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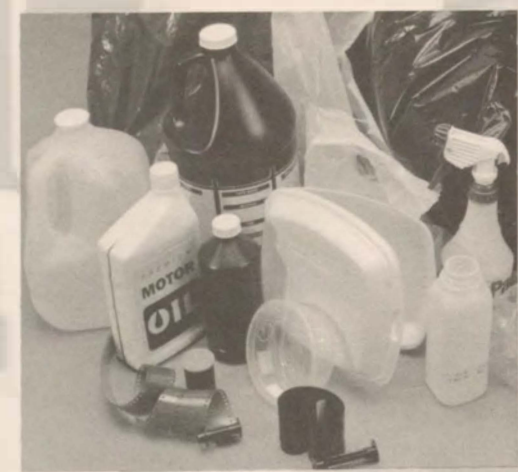
PLASTICS: WASTE MANAGEMENT ALTERNATIVES

USE, RECYCLABILITY, AND DISPOSAL



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California Integrated
Waste Management Board

May 1992

California Integrated
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Preface

This report is on the use, disposal, and recyclability of plastic materials not subject to Division 12.1 of the Public Resources Code. It has been researched and written by staff of the California Integrated Waste Management Board to fulfill the reporting requirements of Public Resources Code 42380.

Acknowledgments

This report was written under the direction of the Market Development Committee of the California Integrated Waste Management Board.

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We would like to express our appreciation for the cooperation received from numerous industry representatives in gathering the information necessary to complete this study.

Table of Contents

Preface i
Table of Contents iii

Executive Summary 1

CHAPTER ONE
Introduction
Pertinent Legislation 5
Scope of Work 5
Organization of Report 6

CHAPTER TWO
Plastics Overview
Introduction 7
Common Types of Plastics 7
Production and Consumption of Virgin Plastics 11
Production of Recycled Plastics 12
Manufacturing Processes for Plastics Products 13

CHAPTER THREE
Plastics in the Waste Stream
Amounts of Plastic Waste 15
Problems Posed by Plastic Wastes 16
Methods for Managing Plastic Waste 19
Conclusions 21

CHAPTER FOUR
Source Reduction of Plastic Wastes
Volume Source Reduction 23
Toxic Source Reduction 24
Source Reduction Studies 25
Methods to Promote Source Reduction 25
Conclusions and Recommendations 27

CHAPTER FIVE
Plastics Recycling
Introduction 29
Curbside Collection 29
Centralized Facilities for Collection 32
Preparing Plastic Wastes for Recycling 33
Reclamation Technologies 35
Conclusion and Recommendations 42

CHAPTER SIX
Markets for Recycled Plastics
Introduction 43
Markets for Industrial Scrap Products 43
Markets for Postconsumer Plastics 44
Exports of Plastic Wastes and Scrap 45
Recent Developments in Postconsumer Plastics Markets 45
PET 46
High Density Polyethylene (HDPE) 47
Polystyrene (PS) 48
Low Density Polyethylene (LDPE) 49
Polyvinyl Chloride (PVC) 49
Polypropylene (PP) 49
Markets for Commingled Plastics 50
Trends in California Markets 50
Conclusion and Recommendations 52

CHAPTER SEVEN
Legislative Initiatives
Introduction 55
Deposits 55
Bans and Restrictions 56
Mandatory Recycling 57
Market Development 57
Government Procurement 58
Plastics Identification 59
Packaging Review Laws 59
Taxes 60
Conclusion 60

CHAPTER EIGHT
Barriers to Source Reduction and Recycling
Introduction 63
Source Reduction Barriers 63
Recycling Barriers (Technical) 63
Economic Barriers 64
Informational Barriers 65
Regulatory Barriers 65
Conclusion 66

APPENDIX ONE
Recycled Plastic Reprocessors and Brokers 67

APPENDIX TWO
California Curbside Programs 71

APPENDIX THREE
Survey Results of California Plastic Reprocessors 75

APPENDIX FOUR
Report on Degradable Plastics 79

LIST OF TABLES AND FIGURES
Table 2.1 (U.S. Plastics by Resins) 9
Table 2.2 (Markets for Plastic Resins) 10
Table 3.1 (Materials Discarded into Waste Stream) 16
Table 3.2 (Plastic Waste Projections) 17
Table 3.3 (Waste Materials by Weight) 18
Table 3.4 (Waste Materials by Volume) 19
Table 3.5 (Postconsumer Plastic Waste) 20
Table 4.1 (Ways for Consumers to Reduce Plastic Use) 25
Table 5.1 (Curbside Collection Programs) 30
Table 6.1 (Typical Processing Costs) 44
Table 6.2 (Exports) 45
Table 6.4 (Plastic Processors in California) 52
Figure 5.1 (Processing Steps) 36
Figure 5.2 (PET Recycling) 37
Figure 5.3 (Polystyrene Recycling Facility) 38
Figure 6.3 (Virgin vs. Postconsumer HDPE Prices) 46

REFERENCES 83

GLOSSARY 87

Executive Summary

Plastic waste is fast becoming the trash of tomorrow. National production of plastics will increase an estimated 33 percent from now until the end of the century, from 58 billion to 74 billion pounds (29 million to 37 million tons) in eight years. Already, plastic waste is one of the fastest growing — and longest lasting — segments of the municipal waste stream.

In just two years, the plastic waste cycle has changed dramatically in California. Scores of collection operations have sprung up and the public has responded strongly to recycling some plastics. Still, the plastic recycling industry is immature, able to recycle and resell only about two percent of the plastic produced in the state. The rest of plastic waste contributes significantly to the filling of California landfills and littering on land and sea. Some plastics waste are also sources of toxic materials — heavy metal additives such as cadmium and lead.

To address the growth of plastic waste, the Legislature in 1990 directed the California Integrated Waste Management Board to report on the use, disposal, and recyclability of plastic materials and containers, under the Public Resources Code, Section 42380. This report is the result of that legislative mandate.

The priorities for dealing with the growing mountain of all waste were established by the California Integrated Waste Management Act of 1989: 1) Source reduction, 2) Recycling and Composting, 3) Transformation (Incineration) and Landfill.

The preferred waste management methods for plastics are source reduction and recycling because of growing landfill and pollution problems.

There are few clear signposts along California's journey to effective source reduction and plastics recycling. Determining which are the most effective programs has been difficult because of a lack of reliable, uniform and accurate data for comparison. Presently, the most promising method of controlling the increasing amounts of plastics in the waste stream appears to be recycling. Contrary to popular belief, most plastics are technically recyclable. Some specific barriers — both to source reduction and recycling — are discussed below.

Barriers: Source Reduction

To discuss source reduction, we must first establish the difference between source reduction and recycling. Source reduction is any action, by either the manufacturer or consumer, that causes a reduction in the volume of waste generated or in its toxicity. Recycling deals with the waste *after* it has been generated.

Source reduction can be accomplished through changes in production, distribution, and consumption. It often requires economic, manufacturing and behavioral changes nationwide. For instance, manufacturers in one state may agree to cease production of one type of plastic but producers elsewhere would still continue production and the plastic would still show up in each state's waste stream.

Some of the possible changes to production methods are to substitute other materials for plastics, reduce the use of toxic additives such as lead and cadmium, or reduce the thickness of a wall of a container. These changes usually require significant research efforts by manufacturers and may affect the performance of a product. For example, thinner walls may undermine the strength of the product, substituting other materials may create safety problems, and using less toxic materials may be more expensive.

Some of the possible changes in consumption habits are for consumers to avoid buying certain products, particularly single-use products, and buy reusable or less toxic products or products that come with less packaging.

Barriers: Plastics Recycling

Plastic waste is generally divided into two categories: industrial plastic scrap and postconsumer.

The market for industrial plastic scrap from manufacturers — which is a small portion of the plastic waste produced — has been active for decades in California because the material has uniform resin, is relatively uncontaminated, and easy to reuse.

Postconsumer plastic recycling, however, still is experiencing significant growing pains because of several barriers:

- Expensive technologies are necessary to clean and separate the different plastic wastes. Although increasing progress is being made in separation and reprocessing technologies, most solutions are costly.

- Labor costs are high because many plastics must be manually separated.

- The market for recycled resins is limited by seasonal fluctuations that lead to an unstable supply, sharp fluctuations in prices for virgin resins, volatile foreign markets, and uneven quality of collected plastic waste because there are no widely accepted standards.

- People simply don't know that most plastics can be recycled. This informational barrier must be overcome so that people can begin to change habits and collect plastics for recycling.

- Existing regulations sometimes put recycling at a disadvantage. Restrictive zoning laws often require, for example, that recycling plants be located far away from sources of plastic waste thereby increasing transportation costs.

- Transportation costs generally are high for plastics due to their low weight and high volume. The amount that any given container can haul is limited without first incurring the cost of compressing and baling.

The Failing of Degradable Plastics

Chemists have been working for some time to develop products that degrade quickly. But degradable plastics are generally an impractical solution for disposal of plastic waste. They are typically unable to photodegrade or biodegrade in modern landfills because of the absence of ultraviolet radiation, oxygen, and moisture. Many serious questions also remain about the toxicity of decomposition by-products associated with degradable plastics.

Degradable plastics also represent a threat to plastic recycling. Although degradable plastics are typically indistinguishable from other plastics, they contain additives that can compromise the integrity and quality of recycled materials if commingled with other plastics.

With the effectiveness of degradable plastics in doubt and effective source reduction involving significant changes, the most immediately achievable option for dealing with the plastics waste stream is recycling.

Recycling that Works

The most actively recycled postconsumer plastic is Polyethylene Terephthalate (PET) beverage containers, which are collected in states with bottle-deposit legislation. Recent growth in the number of curbside collection programs that include plastics will increase the quantity and variety of postconsumer plastic scrap available to reprocessors.

The effectiveness of plastic collection programs varies between communities because of variations in population density, seasonal fluctuations in collection, and citizen participation.

Recycling programs that achieve the highest rates of collection and participation generally include:

- Curbside collection of plastics.
- Supplying collection bins.
- Use of collection vehicles with compaction systems.
- Targeting of PET and High Density Polyethylene (HDPE) containers.
- Public education and promotional programs.

Many European countries continue to aggressively develop plastic recycling programs that often include innovative collection schemes, sophisticated reprocessing technologies, and effective legislation that guarantee a more efficient recovery of plastic wastes.

Recycled resin prices in the United States have generally been 20 percent to 40 percent less than virgin resin prices. In recent years, prices for PET and HDPE recycled resin began to increase because of increased demand for recycled plastic products; however, recycled resin prices dropped significantly in 1991 because of overproduction of virgin resins and the recession. Despite these decreases, recycled resin prices are expected to increase over the next several years.

The increasing demand for these two resins has encouraged collectors and processors to expand their operations. Recycling of polystyrene, polyvinyl chloride, and low-density polyethylene waste may also increase if collection problems associated with these types of resins can be overcome.

Recent developments in chemical recycling of plastics are broadening the possibilities for using recycled resins in applications dominated by virgin resins, such as food-contact products; however, chemical recycling requires costly equipment that may limit its use to large chemical and resin manufacturers. Currently PET is the only resin being chemically recycled on a commercial scale.

California

Although few statistics are available to quantify the state's recycling of plastic wastes, California generally is behind eastern states; however, California's plastic waste infrastructure is improving. To help establish a solid recycling industry, the California Legislature has established tax credits for firms buying recycling equipment, has passed minimum-content legislation for trash bags and rigid-plastic containers, and has established procurement goals for state government for the purchase of products containing secondary resins. Collections are increasing of PET and HDPE containers through curbside collection programs and the bottle-redemption law, and the state's postconsumer plastic recycling and reprocessing capacity has increased.

The majority of the state's plastic processing industry is in the Los Angeles Basin. In the near term, efforts to increase the collection and marketing of recycled plastics could be productive sooner in this area of California with later efforts directed statewide.

Several actions have already been taken to develop a solid foundation of information. The California Integrated Waste Management Board has established CalMAX, a free service designed to help businesses find markets for materials they traditionally discarded through a catalog that lists both needed and available materials. The Board will expand its role as an information clearinghouse on source reduction and recycling issues. The clearinghouse will collect and disseminate information on existing programs, existing and current research, and other information that will assist the commercial sector and local governments in pursuing source reduction and recycling efforts.

The Board currently is engaged in the development of several programs to increase the recycling of a host of materials. Besides the tax credit program mentioned earlier there is a Recycling Market Development Zone program under development which would provide assistance to businesses located in the zones on permit issues and California Environmental Quality Act requirements, and make available low-interest loans for the use or production of recycled materials, somewhat similar to enterprise zones.

The Board is also studying the feasibility of imposing advance disposal fees on certain commodities to cover the costs of recycling or disposal and is working with local governments to institute source reduction and recycling programs.

Recommendations

In proposing the following recommendations, the Board does not intend to single out plastics for separate consideration. The Board is developing a market development strategy and will determine how best to target limited resources.

For the Board and Legislature to promote the reduction, reuse, and recycling of plastics, programs should be developed that would provide:

1) assistance to communities and manufacturers through development of a computer model for evaluating plastics collection options;

2) educational materials to schools promoting source reduction by the consumer;

3) support for research programs on source reduction technology at universities in the engineering curriculums;

4) for the development and establishment of performance standards for recycled resins through a coding system;

5) support of legislation to mandate a reduction and eventual phase-out of the use of heavy metals such as lead and cadmium in packaging, including plastic packaging. The mandate should include a study to determine a reasonable time frame for

phasing out heavy metals and suggest methods to facilitate research in developing alternatives;

6) grants for plastics recycling technologies and activities such as research and development, automated resin separation, chemical recycling, purchase of baling and sorting equipment for shipment;

7) loans for the acquisition of recycling equipment by plastic reprocessors and manufacturers.

The Board also recommends avoiding legislation that ban plastics. Such laws usually fail to be successfully implemented because they are based upon insufficient scientific data about the environmental impacts or recyclability of plastic wastes.

The Board is conducting a plastics marketing study identifying California manufacturing firms that may be able to use recycled plastics (PRC §42373). The study will also examine if incentives, such as tax credits or subsidies, would assist plastic processors to increase the use of recycled resins.

The key to developing a healthy and growing market for postconsumer plastics in California is to encourage the existing plastics processing industry currently concentrated in southern California to use recycled plastics. As plastics recycling becomes successful there, or new processors come on-line elsewhere, techniques can be transferred throughout the state. By making these and other investments, California can help the fledgling plastics industry develop the solid infrastructure it needs to recapture plastics before they become the trash of the future.

Chapter One

Introduction

Pertinent Legislation

This report was researched and designed to fulfill the mandate created in 1990 by Public Resources Code Section 42380:

The (California Integrated Waste Management) Board shall prepare and submit to the Governor and the Legislature a report on the use, disposal, and recyclability of plastic materials and containers not subject to Division 12.1 (commencing with section 14500) of the Public Resources Code. The report should include, but not be limited to, all of the following:

(a) A description of barriers to plastics collection, separation, and recycling for reuse.

(b) A description and comparison of current methods used in the state, other states, and other countries to reduce the use of, and recycle, plastic materials currently disposed of in the state and recommendations on how the state might reduce or recycle plastic materials.

(c) A description of programs under development and potentially available for plastics collection and recycling.

(d) A description of current domestic and foreign markets for recycled plastic materials, and recommendations on how the state could improve the marketability of these materials.

Scope of Work

This report describes an immature industry; one with significant potential, but few current figures, or even comparable statistics, with which to measure progress.

National studies of postconsumer plastic waste are developing. Until 1990, plastic waste was largely measured by weight. But because of the high volume-to-weight ratio of plastic, that measurement was deceiving. By volume, plastics account for about three times as much waste — almost 20 percent of the waste in landfills.

To give an accurate perspective of the rapidly changing plastics industry in California, figures are compared over time, when possible. National and state figures are used to establish the percentages of plastic in the waste stream.

The hierarchy for dealing with plastics in municipal solid waste was established by the Integrated Waste Management Act of 1989 (Act). The information on source reduction — the top priority on that list — is largely anecdotal. Examples of source reduction efforts by private industry, governments and other organizations are included to give an idea of the possibilities.

Although this report includes both national and international examples of collection programs and technology, the report emphasizes California examples. When this report was mandated, postconsumer plastics recycling was virtually nonexistent in California. In just two years, scores have sprung up, providing a better base for comparison.

Research on markets for recyclable plastic waste included state, national and foreign markets. The research focused on foreign markets, which now buy most of California's plastic recyclable waste, and southern California, where a thriving plastics industry provides a significant potential market for recycled plastics.

Although there are hundreds of formulations of plastics, the report primarily focuses on the most common varieties. Similarly, the most representative legislative initiatives from across the nation are used to examine effective legislative strategies.

Overall, the base of data is thin because the post-consumer plastics recycling industry is new, making it difficult to quantify programs and markets. Also, the industry is dominated by entrepreneurs, who tend to be protective of data or not keep them, and there are no standards — which makes comparisons difficult.

Even so, there is enough information available to satisfy the legislative mandate and to provide an overview of plastics use, recycling and waste.

Organization of Report

The report overview begins in Chapter 2, explaining the common types of plastics, the structure and size of the virgin plastics industry, and a brief overview of the plastics recycling industry.

Chapter 3 discusses plastics in the waste stream. Plastics are compared to other wastes in terms of both weight and volume. The sources of plastic waste are discussed, as well as the special problems of litter and toxicity that plastics waste pose. Methods of handling plastic waste are prioritized according to a hierarchy of waste management practices established by the Integrated Waste Management Act of 1989, and methods of disposal are described and compared.

The top priority for managing plastic waste, as established by the Board, is examined in Chapter 4: Source Reduction of Plastic. Methods of source reduction include reducing the volume of plastics used at both manufacturing and consumer levels. Source reduction studies are cited, though none provide a comprehensive view, and methods to promote source reduction — including education, and government and industry research — are recommended.

The development of technologies and the boom in curbside recycling programs throughout California are developed in Chapter 5. The first part of the cycle of recycling is discussed, including the collection, separation, reclamation and manufacture of recycled plastics. Examples of successful technologies and collection programs are drawn from within California, other states and other nations. The last part — Marketing, a key element in recycling — is covered in Chapter 6.

The markets for recycled plastics are broken into two main categories: industrial scrap and postconsumer plastics. Price comparisons are made between virgin and recycled resin because the difference in cost is a major factor in the success or failure of developing dependable markets for recycled resin. The dangers of relying too heavily on volatile foreign markets for California postconsumer plastics are also detailed, as are recommendations for establishing a recycling market in southern California.

The barriers to plastics recycling are broken out separately, in Chapter 7, because they will be essential to overcome to establish plastics recycling in California. The biggest obstacles to plastics recycling are technical (because of the variety of plastic types), economic (which include the cost of collecting and buying sophisticated machinery, as well as the problem of inconsistent supplies and undeveloped markets), informational (including the perception that plastics are largely unrecyclable), and regulatory barriers (including laws that promote landfilling or incineration, and taxes and zoning that make recycling unprofitable or impractical).

Legislative initiatives relating to the plastics industry have had differing degrees of success. Chapter 8 compares taxes, bans, deposits and mandatory recycling throughout the United States and in other countries.

A separate section on degradable plastics was included as an appendix because this method of reducing plastic waste has been found to be impractical in modern solid waste landfills.

Other appendices are included to detail the firms and programs involved in recycling in California.

Chapter Two

Plastics Overview

Introduction

In a little more than a century, plastics have been woven into the fabric of our society. Their amazing versatility has allowed the manufacture of an enormous number of products — as mundane as beverage straws and as critical as artificial hearts.

Beginning with the development of Celluloid to replace ivory in 1868, plastics rapidly became an important substitute for natural materials such as wood, leather, paper, metal, glass, and natural fibers.

The development and manufacture of plastics accelerated with the growth of the petrochemical industry in the 1920s and shot up even more during World War II, with the need for synthetic replacements for natural materials.

Since then, demand for plastics has grown at a steady pace. Annual plastics production topped one billion pounds during the mid-1940s. Current annual plastics production is nearly 60 billion pounds (30 million tons), and industry projections estimate production may top 75 billion pounds (37.5 million tons) by 2000.

Plastics are synthesized from ingredients such as petroleum, natural gas, coal, and wood. Individual types of plastics, or resins, consist of various combinations of carbon with hydrogen, oxygen, nitrogen and other organic and inorganic molecules. These elements form small molecule groups called monomers, which are linked together through the chemical process of polymerization into long chains of molecules called polymers. Different types of plastic resins are created during the polymerization process by using different ingredients, catalysts, additives, and variations in temperature, pressure, and reaction time. The polymerization process culminates in the manufacture of plastic resins, each with a wide range of strength, toughness, density, brittleness, and opacity. Resins are the raw materials used by manufacturers to make a variety of plastic products.

Plastics have become more popular because they fit a variety of manufacturing needs:

- The strength, durability, and low weight-to-volume characteristics of many plastics minimize raw materials costs and maximize product quality and ease-of-use for consumers.

- The materials used to produce plastics — traditionally inexpensive feedstocks such as oil and natural gas — keep costs relatively low.

- Many resins can be easily produced and molded at lower than normal temperatures, which require fewer energy inputs.

Common Types of Plastics

All plastic resins are either thermoplastics or thermosets.

The Thermosetting plastics

Thermosetting plastics are composed of polymer chains that harden and permanently cross-link with adjacent polymer chains during the resin manufacturing process. These cross-linkages create more durable resins with high-performance characteristics necessary for specialized applications in medicine, aeronautics, and automotive engines.

The number of these different engineering plastic resins has rapidly multiplied in recent years, especially with the introduction of high-performance consumer packaging, such as microwaveable trays. This proliferation of industrial and consumer applications has made engineering plastics one of the fastest growing segments of the plastics industry.

Cross-linked polymers, however, cannot be remelted and reformed into new products, and are typically excluded from plastic recycling efforts. Recent research indicates that some thermosetting

plastics may eventually be recyclable using developing chemical recycling technologies. (More detail in Chapter 5).

Recyclable Thermoplastics

Thermoplastics are composed of polymer chains that can be melted or hardened by temperature changes during the manufacturing process. The ability to reheat and reform thermoplastics several times without serious damage to the resin has made them the target of most plastic recycling efforts in the United States.

As shown in Table 2.1, thermoplastics such as polyethylene, polypropylene, Polyethylene Terephthalate (PET), and polystyrene accounted for 85 percent of U.S. plastics production. While thermosetting plastics accounted for just under 15 percent of the total, they are becoming more popular among manufacturers because of their durability and heat-resistance characteristics.

The plastics industry uses a profusion of resin blends and configurations. The majority of plastics products, however, are manufactured from a much smaller set of resins. Many of these resins can be readily identified by the visual and physical qualities of the resin. Some closely similar resins, however, are not readily identifiable and pose problems for recycling operations that must separate plastic wastes by resin type.

Here are the most commonly used resins:

Polyethylene, the most widely used resin in the United States, accounted for 35 percent (21,336 billion pounds) of resin sales in 1991. High density polyethylene (HDPE) is used to produce the majority of rigid containers for dairy, detergent, cosmetics, and auto products, such as antifreeze and motor oil. HDPE resin is widely used because of its low cost, toughness, and flexibility. Low density polyethylene (LDPE) is used to make plastics film products, such as trash bags, grocery sacks, and dry cleaning bags. LDPE is especially convenient in packaging materials because it is moisture-proof and chemically inert. Most polyethylene products have short product life spans of under one year; however, they are also used in some durable products with longer life spans such as toys, buckets, drums, pallets, and automotive parts.

Polypropylene (PP), another thermoplastic, is used in consumer products such as ketchup bottles and cellophane-like wrappers for snack foods and candy. Polypropylene, however, is more commonly used for more durable products such as furniture, auto battery cases, fish nets and auto fenders. Polypropylene has low density, rigidity, and is resistant to heat and chemicals.

High density polyethylene, low density polyethylene, and polypropylene share similar hydrocarbon feedstocks (i.e. ethylene) and are commonly referred to by the generic term polyolefins. The polyolefin resins are often referred to as "commodity" plastics because of their high versatility and relatively low price. Polyolefins are the most pervasive plastics and account for more than 48.7 percent (29,491 billion pounds) of all U.S. plastics production. In recent years, researchers have developed several cross-over applications for polyolefin resins, including many grocery bags, which are made of HDPE, and some rigid items, which are made of LDPE.

Polystyrene (PS) is often mistakenly referred to as "styrofoam," which is actually Dow Chemical's trademark name for the material used in products such as disposable coffee cups. Although PS foam products such as coffee cups are readily identifiable, PS resins are also used in a variety of different styrene products with distinctly different appearances:

- ***Expanded or foamed PS*** is the most widely recognized PS resin and is used in a variety of products including packing and insulation materials, cups for hot beverages, and fast food hamburger "clamshells."

- ***Oriented or "crystal" PS*** is used to make clear deli and salad trays and some film products.

- ***Semi-rigid PS*** is used to create slightly pliable products, such as dairy product containers and beverage cup lids.

- ***High-impact PS*** is used to produce rigid items such as plastic cutlery, disposable razors, and some prescription drug containers.

- ***Acrylonitrile butadiene styrene (ABS),*** commonly used to make telephone casings, plumbing and sewer pipes, is another member of the styrene family of resins.

In recent years polystyrene has received considerable environmental scrutiny, with some local governments, such as Berkeley, banning the production or

TABLE 2.1
1991 U.S. Plastic Sales by Resin
(In millions of pounds)

THERMOPLASTIC RESINS	SALES	PERCENT
Low-density polyethylene (LDPE)	12,143	20.0
Polyvinyl chloride and copolymers (PVC)	9,130	15.1
High-density polyethylene (HDPE)	9,193	15.2
Polypropylene and copolymers (PP)	8,155	13.5
Polystyrene (PS)	4,877	8.0
Thermoplastic polyester (PET, PBC, PCT)	2,549	4.2
Acrylonitrile/butadiene/styrene (ABS)	1,125	1.9
Other styrenics	1,180	2.0
Other vinyls	120	0.2
Acrylics	672	1.1
Polycarbonate	601	1.0
Thermoplastic elastomers	584	1.0
Nylon	556	0.9
Polyphenylene-based alloys	195	0.3
Polyacetal	140	0.2
Styrene/acrylonitrile	117	0.2
Celluosics	84	0.1
Total — Thermoplastic resins	**51,421**	**84.9**
THERMOSETTING RESINS		
Polyurethane	2,985	5.0
Phenolic	2,556	4.2
Urea and melamine	1,467	2.4
Polyester, unsaturated	1,081	1.8
Epoxy	428	0.7
Alkyd	315	0.5
Total — Thermosetting resins	**8,832**	**14.6**
Others	**345**	**0.5**
Totals	**60,598**	**100.0**

Source: Modern Plastics, January 1992

TABLE 2.2
U.S. Resin Sales to Major Markets

MARKET CATEGORY/ PRODUCT AREA	MILLIONS LBS.	% OF U.S. SALES
PACKAGING		
Containers(a)	7,443	
Film	5,636	
Coatings	1,178	
Closures	830	
Total Packaging	**15,087**	**25.0**
BUILDINGS AND CONSTRUCTION		
Pipe, fittings, conduit	4,102	
Insulation	1,041	
Panels and siding	954	
Profile extrusion	378	
Vapor barriers	329	
All other	3,969	
Total Buildings, Construction	**10,773**	**17.8**
CONSUMER AND INSTITUTION PRODUCTS		
Housewares	1,503	
Appliances	1,190	
Toys	798	
Total Consumer and Institution	**3,491**	**5.8**
TRANSPORTATION		
Cars, vans, light trucks	1,956	
Other	239	
Total Transportation	**2,195**	**3.6**
ELECTRICAL AND ELECTRONICS		
Electrical and Electronics	**2,089**	**3.4**
FURNITURE		
Furniture	**1,045**	**1.7**

(a) Includes bases for PET bottles

Source: Modern Plastics, January 1992

sale of some polystyrene products. These bans originated out of environmental concerns regarding the production of ozone-depleting gasses during PS foam manufacturing, the slow disintegration of PS products (estimates range in the hundreds and even thousands of years), and the widespread utilization of PS in single-use products such as fast food packaging.

Polyethylene terephthalate (PET), the most widely recycled plastic resin, belongs to the polyester family of plastic resins and is most commonly used to produce plastic soft drink and beverage bottles because of its toughness, clarity, and excellent barrier properties. The overwhelming use of PET for beverage packaging and the ease of identifying PET beverage bottles has stimulated several states, including California, to include these containers in their beverage-container redemption programs. Other products made from PET resin include clear bottles for various food and non-food products, sheeting, blister packs, and some durable goods, such as carpets and auto parts.

Polyvinyl chloride (PVC) resin is widely used in building and construction products such as pipes, siding, conduits and gutters because of its strength and durability. PVC resin can also be readily modified with additives that make it useful in a variety of products, such as bottles, flooring, plastic wraps for food, and as a leather or rubber substitute on luggage and brief cases.

Production and Consumption of Virgin Plastics

The plastics industry can be divided into those firms that manufacture or add value to plastic resins, and those that process plastic resins into finished products. Plastic processing firms represent the much larger sector both in terms of sales and workforce.

Resin manufacturing typically occurs at large petrochemical plants, most of which are concentrated in the Gulf of Mexico and in the Atlantic Coast states. The industry consisted of 480 firms, employed 56,300 workers and generated $26.24 billion on resin shipments in 1987. The states with the largest employment in resin manufacturing are Texas, New Jersey, West Virginia, Pennsylvania, Louisiana, Ohio, Michigan, and California. California has 67 plastic manufacturers who employed more than 2,100.

Many resins require additional processing before they can match the color, quality, safety, and other specifications for many plastic products. Additives typically alter the physical characteristics (for example, flame retardance, flexibility, lack of electrical conductivity) or add aesthetic qualities (for example, color, transparency, brightness) to plastic resins. Many additives are incorporated into resins during both the resin manufacturing process and during the production of plastic products.

The plastic processing industry buys virgin and recycled resins and processes them into a variety of forms and products for packaging, consumer and industrial uses.

Plastic processing firms are smaller, more numerous, and more geographically decentralized than resin manufacturing firms. More than half of the 12,000 plastics processing firms in the United States employed fewer than 20 employees in 1988, the latest year for which statistics are available. In total, these companies employed 580,000 workers and generated $60.5 billion in product shipments in 1987. In California, almost 1,700 plastic processing firms employed more than 64,000 workers and generated shipments in excess of $6.7 billion in 1987.

Packaging products made up the largest sector of the plastic processing industry, accounting for more than 33.5 percent of all U.S. plastic sales in 1987. Building and construction applications were the next largest sector at 24.8 percent. The market share of these and other significant market sectors are highlighted in Table 2.2

Because production of commodity plastics such as HDPE and LDPE is concentrated in large complexes that produce huge volumes, the opening or closing of a single production facility can significantly affect resin supply and prices. The plastics industry has been characterized by swings in product prices because of rapid increases in production capacity, sudden increases in feedstock prices, and national economic downturns that reduce demand for plastic products in industries such as construction.

Today, the recession has constricted consumer and construction markets sending commodity plastic supplies up and prices down. In 1991, U.S. resin production dropped one percent. Although this may not seem to be a major drop compared to some other industrial sectors, it represents a significant change from the plastic industry's 5.2 percent compound growth rate from 1980 to 1990.

Production of Recycled Plastics

Plastic recycling involves the transformation of plastic wastes into useable plastic, typically in the form of finely shredded flakes or resin pellets. Because the source and makeup of plastic wastes strongly affect the processing and markets for recycled resin, a number of different industries are involved in the plastics recycling industry.

Some plastic is recycled by the firms which manufacture or process virgin resins. The characteristics of some resins and manufacturing processes allow resin manufacturers and plastic processors to directly recycle some manufacturing waste products such as floor cuttings and overruns. However, most plastic waste cannot be directly reused and is given or sold to firms that can process the waste into more useable forms. Plastic waste materials generated by the plastics industry are referred to by a number of names including plastic scrap, industrial plastic wastes, or secondary plastic wastes.

Although most of the raw material used in the production of recycled plastics currently consists of plastic scrap, the bulk of plastic waste is generated in commercial and residential waste streams in the form of packaging, construction materials, and various consumer products. This type of plastic waste generally contains more non-plastic contaminants and a greater mixture of different resins than industrial plastic wastes. Although various classifications have been used to describe the various types of plastic wastes in commercial and residential wastes streams, these materials are often generally referred to as postconsumer plastic wastes.

Because postconsumer plastics originate from a much larger number of sources than scrap plastics, many private or government-funded groups have been established to collect these recyclable wastes. The groups include both private and government waste haulers, curbside collection programs, local recycling programs, local collection centers for recyclables, entrepreneurial firms, and large organizations sponsored by the plastics industry. All of these groups can be generically referred to as collectors. No reliable statistics exist for the number of collectors nationally; however, California has more than 280 curbside collection programs, 2100 state-certified beverage container buyback centers, and at least 650 drop-off centers run by non-profit organizations, small firms, and individuals (See Appendix 2). Most general collectors take PET containers.

Plastic waste and scrap is sold to handler/brokers and reprocessors because it needs additional processing before it can be reused by plastic manufacturers. Handler/brokers often bale or grind plastic wastes for sale to domestic and foreign reprocessors or plastic manufacturers. Reprocessors typically use various manual and automated techniques to more completely reprocess plastic wastes. These techniques may include separation of plastics from other waste and by resin type, washing, shredding, grinding, remelting, and extrusion. Government statistics are not available for the plastic reprocessing industry because most of the industry consists of small entrepreneurial firms. However, the 1990-91 Directory of U.S. & Canadian Scrap Plastics Processors & Buyers identified more 150 handler/brokers and reprocessors in the United States. The Board has currently identified more than 20 reprocessors in California (See Appendix 1).

The production of most recycled plastic involves the direct recycling or reprocessing of plastic scrap that is generally free of non-plastic contaminants and consists of the same resin. This reduces processing costs for reprocessors and results in recycled plastic material which may closely match the quality of virgin resins. There is relatively little recycling or reprocessing of mixed resins currently.

Few reliable production or market statistics exist for either scrap or postconsumer plastics. This lack of information reflects the reluctance of resin manufacturers and plastic processors to reveal information which demonstrates the market advantages of recycling and reprocessors who are concerned about releasing information which may be advantageous to their competitors.

Quality issues dominate the production and markets for recycled plastics because many products have strength, color, health, and other specifications that are often unattainable by recycled resins. Improving reprocessing technologies, changing consumer attitudes, and government mandates, however, are encouraging the reevaluation of some specifications and leading to the development of new applications for both scrap and postconsumer plastic materials (See Chapter 6 for a more complete discussion).

Manufacturing Processes for Plastic Products

Most thermoplastics begin as small pellets, which are mixed with additional additives and fed into machines that mix, melt, and mold the resins into plastic products.

Thermosetting resins are typically shipped in liquid form so that processors can mold and "cure" the resin into a permanently hardened shape formed from cross-linked polymers.

Here are some of the common methods of processing plastics:

Blow molding is used primarily with thermoplastics to manufacture hollow plastic products, such as bottles. Melted resin is formed into a tubelike shape called a parison, which is then sealed at both ends and injected with air. The inflation of the molten plastic tube forces the plastic against the inside of a mold. The finished piece is ejected from the mold after cooling.

Calendaring is used to process thermoplastics into plastic films and sheets, and also to apply plastic coatings to fabric or paper. Heat-softened plastic material is passed between two or more heated rollers which revolve and squeeze the material into a continuous sheet.

Extrusion is typically used to form thermoplastic resins into continuous sheeting, tubes, rods, film, and other shapes. A hopper feeds dry plastic resin into a long, cylindrical heating chamber. The action of a continuously revolving screw forces molten resin out of the chamber through a small opening or die and into the shape of the finished product. Blowers or water cools the plastic as it leaves the die.

Coextrusion is a similar process which simultaneously pushes multiple layers of different resins into the die. This technique is starting to be used to sandwich a layer of recycled resin between layers of virgin resin during the manufacture of products such as laundry detergent bottles.

Foam plastic molding can be used in tandem with several manufacturing techniques. Foaming processes involve adding blowing agents in the resin that decompose with heat and generate the gasses needed to create open or closed cellular structures within the resin. For example, steam is used to expand polystyrene resin beads in products such as cups and plates.

Injection molding forces granulated resins through a heated cylinder and into a relatively cool mold held closed under pressure. Once the mold cools, the plastic resin cures, hardens, and is removed.

Casting uses both thermosetting and thermoplastic resins to produce shapes, rods, and tubes. Heated liquid resin is poured into an open or closed mold, where it cools into a solid.

Compression molding is the most common method of forming thermosetting materials. Resin mixed with additives are placed into a pre-heated mold which is closed under pressure. While the mold continues to be heated, the material undergoes chemical change and hardens into the desired shape.

Chapter Three

Plastics in the Waste Stream

Introduction

Data and estimates vary, but the trend is unmistakable: plastics represent a significant and growing portion of the waste stream.

In 1960, about 500,000 tons of plastic were discarded nationally. By 1986, more than 10.3 million tons entered the waste stream. That trend will continue, according to a 1988 study conducted by Franklin Associates for the U.S. Environmental Protection Agency (US EPA) which estimates that plastics in the waste stream may nearly double between 1984 and 2000 (see Table 3.1).

Californians discarded 2.97 million tons of plastics in 1990, representing about 7.8 percent of the 40.51 million tons of solid waste disposed of in the state, according to a preliminary Board study (see Figure 3.2).

The study - the first to attempt to measure plastics in the state solid waste stream - also found that Californians were beginning to recycle. About 137,000 tons of plastic wastes were diverted from the state's landfills in 1990 through recycling and transformation activities. The statistics were compiled by the Board from a sample of 122 preliminary drafts of waste generation studies submitted to the Board by local jurisdictions.

Plastics make up about the same portion of the national solid waste stream — eight percent by weight — according to the US EPA's 1990 report on municipal solid wastes.

The US EPA study also indicated that there was a significant difference between the weight and volume of plastics in the waste stream. The light but bulky nature of many plastic products such as bottles and foam packaging makes plastics a significant contributor to the volume of the waste stream. Plastics account for 19.9 percent by volume nationally, according to the US EPA study (see Figure 3.4), and some other studies estimated volumes as high as 30 percent.

Sources of Plastic Waste

In the United States, there are three primary groups of contributors to plastic waste. The first two generate plastic scrap or industrial plastic waste:

1. Resin manufacturers generate plastic waste when a resin that does not meet specifications is beyond salvage and must be discarded.

2. Processors produce plastic wastes in the form of trimmings, overruns, and discards while manufacturing plastic products.

The last category is generally known as postconsumer waste:

3. Commercial establishments and individual consumers produce waste by discarding packaging materials and disposable products. This source contributes most directly to the plastics found in municipal solid waste.

Of the three million tons of plastic waste generated annually in California, about half is residential, while the other half is a combination of commercial and industrial, according to the 1990 Tellus report. (Commercial and industrial sources of plastics waste were not broken out in the study.)

Packaging is the largest source of plastic waste found in the municipal solid waste stream. In 1984, 53 percent of all discarded plastics came from packaging. Packaging is also the fastest growing market for plastics: In 1977, the production of disposable packaging was 7.9 billion pounds, and in 1985 it was 12.8 billion pounds. Clearly, packaging will become an even larger source of the plastics in municipal solid waste.

TABLE 3.1
Materials Discarded into the Municipal Waste Stream from Residential and Commercial Sources
(In millions of tons and percent)

	1970		1984		2000	
Material	Tons	%	Tons	%	Tons	%
Paper and Paperboard	36.5	33.1	49.4	37.1	65.1	41.0
Glass	12.5	11.3	12.9	9.7	12.1	7.6
Metals	13.5	12.2	12.8	9.6	14.3	9.0
Plastics	3.0	2.7	9.6	7.2	15.5	9.8
Rubber and Leather	3.0	2.7	3.3	2.5	3.8	2.4
Textiles	2.2	2.0	2.8	2.1	3.5	2.2
Wood	4.0	3.6	5.1	3.8	6.1	3.8
Food Wastes	12.7	11.5	10.8	8.1	10.8	6.8
Yard Wastes	21.0	19.0	23.8	17.9	24.4	15.3
Misc. Wastes	1.8	1.7	2.5	1.9	3.2	2.1
Total	**100.3**	**100.0**	**133.0**	**100.0**	**158.8**	**100.0**

Source: Franklin and Associates, 1988

Problems Posed by Plastic Wastes

Some of the basic problems caused by plastics wastes are related to their characteristics.

Plastics are light in weight, and some are strong and durable. They are resistant to many types of corrosion, decomposition, and chemical attack. Because the resins decompose slowly, if at all, plastic wastes remain indefinitely in landfills or bodies of water. For example, many plastics have a life expectancy of 450 years.

Most plastics are easily manufactured from materials of relatively low cost, and they frequently end up in products that are inexpensive and disposable.

The very characteristics that make plastics such versatile materials for design and manufacture of products complicate the management of their waste.

There are more than 2,000 different types of plastics, each with a distinct chemistry that may make it partially or completely incompatible with other resins. The chemical incompatibility of different resins generally forces separation of plastic wastes by resin type to process high quality recycled materials. Plastics also come in a variety of different colors which also may need to be separated by color to create marketable recycled material.

Some resins and some additives produce toxic emissions when incinerated. In addition, some additives, such as lead, mercury, chromium and cadmium leave ash that is considered hazardous material.

Polyvinyl Chloride (PVC) in particular has been plagued by controversy over the potential for PVC waste to create hazardous emissions in incinerators and the possibility of carcinogenic leaching from PVC food containers in landfills. Many recyclers, in addition, are troubled by the increasing use of PVC in consumer bottles because of PVC's visual similarity and chemical incompatibility with PET, which could undermine recycling efforts.

The volume of discarded plastics — such as films, bottles, foam packaging, and disposable food service products — combined with their tendency to resist compaction causes them to represent a much more significant presence in the nation's dwindling number of landfills than their weight would suggest. While plastic accounts for roughly 20 percent of the municipal solid waste stream by volume today, this percentage is likely to increase as recycling and composting of the largest components of the waste stream — paper and organics — becomes widespread.

Litter

On land, plastic litter is encountered along roadsides, in vacant lots, on beaches, and sometimes in parks and other public places. This litter is unsightly and long lasting. Though few studies have been undertaken to determine the extent of the problem, the Center for Environmental Education maintains this litter may pose a fire danger and become a hazard to wildlife.

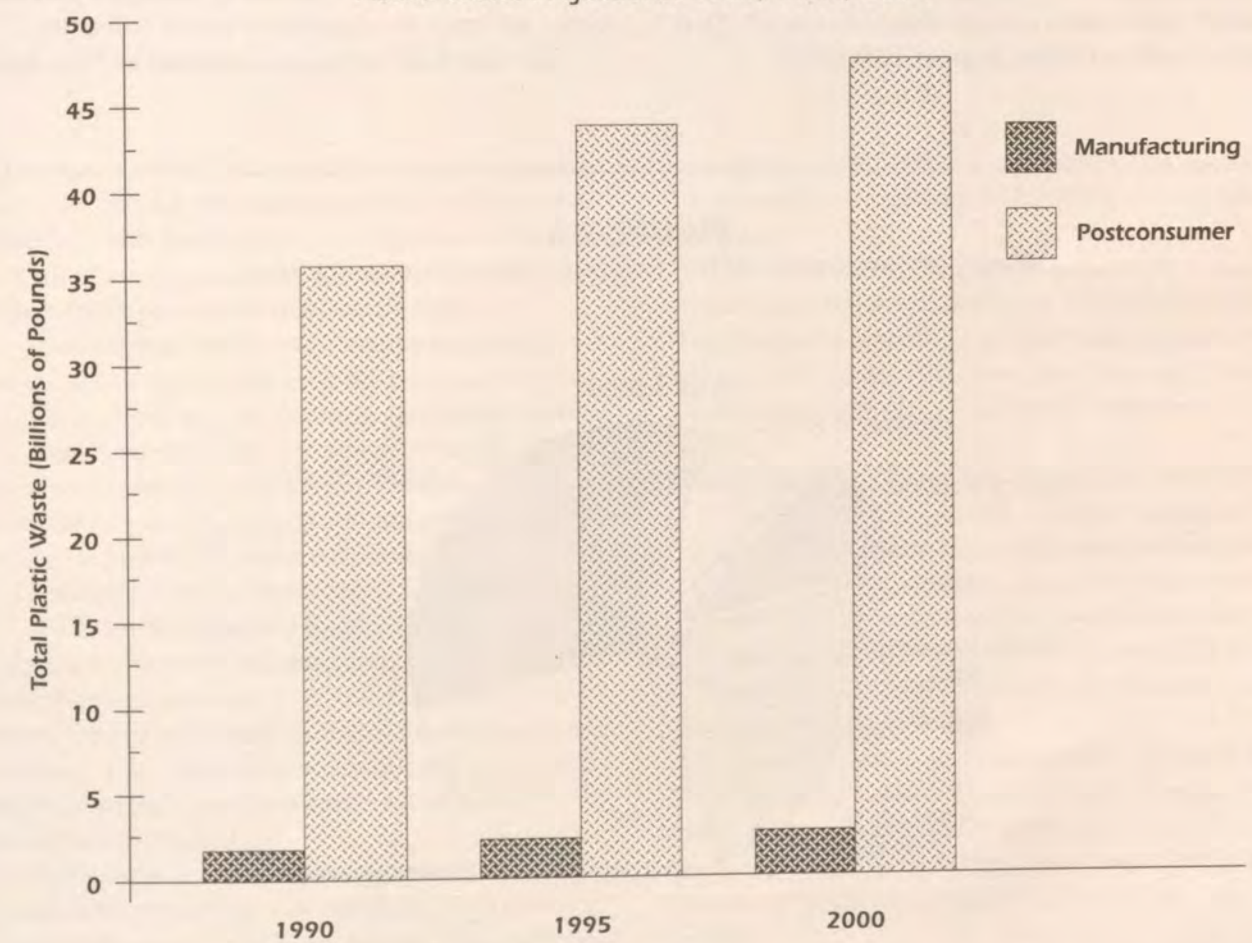
The effect of plastic litter in the oceans and other bodies of water is better documented. The Center for Environmental Education has estimated that merchant ships alone toss 639,000 plastic containers into the ocean every day. Environmentalists estimate that about one million tons of plastics per year are dumped from ships worldwide. Lost plastic drift nets also contribute to ocean litter. Fishermen from Taiwan, Korea, and Japan, for example, lose about 1,800 miles of plastic net per day during the five-month fishing season.

Plastic litter in the ocean comes mainly from dumping of waste from ships, commercial fishing, recreational boats, storm-water runoff, and sewer overflow.

The effects of plastic litter on marine life are also well documented — and alarming.

Each year more than 100,000 marine mammals die by ingesting plastics that resemble jellyfish, according

FIGURE 3.1
Plastic Waste Projections: 1990, 1995, 2000



Source: Oak Ridge National Laboratory, May 1990

to an estimate by the Entanglement Network, a coalition of 18 environmental groups. Two million sea birds a year are reported dead, victims of suffocation or intestinal blockage from ingested plastics. Plastic pellets, razor blades, foam cups, rings, straps, and toys have all been retrieved from the gullets of dead seabirds, fish, and mammals.

Another dangerous segment of plastic litter is disposable medical and laboratory items, which account for a growing proportion of the waste stream. In 1989, about one billion pounds of plastic went into eight major medical device and packaging markets. Of this total, 325 million pounds was PVC, which was used in numerous applications: 98 million pounds in kits, 80 million in tubing, 60 million in intravenous bags, and 10 million pounds in blood bags.

About 80 percent of this material is disposed of on-site, mostly by burning, and 20 percent off-site by landfilling. In California, a number of small incinerators in hospitals have closed because of strict control measures suggested by the state Air Resources Board. Many of those wastes are now shipped to special facilities for treatment before disposal in landfills.

Methods for Managing Plastic Waste

Methods for handling most solid wastes, including plastics, can be broken into two categories: methods for reducing the amount of waste before it is generated, and those for disposal of waste after it has been generated. The former includes source reduction and reuse of products, while the latter includes recycling, incineration, and landfill.

The Legislature, under AB 939, listed the following Integrated Waste Management hierarchy to deal with solid wastes in California:

(1) Source reduction

(2) Recycling and composting

(3) Incineration/landfill

Methods for Reducing the Amount of Plastic Waste

The most desirable method of managing plastics under the legislative mandate is source reduction.

The Board defines source reduction as "any action that causes a net reduction in the generation of solid waste. It includes the reduction of both volume and toxicity." This concept has two components: less production of material, and production of material containing fewer potentially toxic substances.

Source reduction not only conserves natural resources and reduces the need for incineration and landfill, it also makes incineration and landfill safer by reducing toxic materials. However, efforts to carry out source reduction may affect the quality or performance of consumer products and the recyclability of plastics. (Chapter 4 deals in detail with the problems and potential of source reduction.)

While source reduction focuses on changes in design, manufacture, and purchase, reuse focuses on using the same product. Some refillable plastic containers are already manufactured for some liquids and powders. These include containers for spring water, cleaning liquids, pool chemicals, bulk powdered goods, and shopping bags.

Technology for manufacturing reusable containers is constantly improving. For example, GE Plastics recently introduced a refillable half-pint polycarbonate milk bottle to replace high-density polyethylene-coated paper cartons in New York. The bottles can be reused up to 100 times and then can be reground for use in non-food products, such as crates and building products.

In another example, the Schroeder Milk Company of St. Paul, Minnesota, developed a returnable HDPE 1-gallon milk jug that can be reused as many as 50 times. And Canada and Brazil are beginning to experiment with refillable PET soft drink containers.

Methods for Disposal of Plastic Waste

The process of converting discarded waste materials into useable materials or products is called recycling. The California boom in recycling has spurred the industry to expand from 16 Materials Recovery Facilities (MRF) in 1989 to 59 by the end of 1991. These facilities are the bridge between the generators and buyers of recyclables.

The most recoverable plastics are bottles and film. They are made from two basic types of plastics: PET (Polyethylene Terephthalate), which is a more flexible plastics popular for soda containers, and HDPE (High Density Polyethylene), which is a harder, stronger plastic.

Other plastics, including construction-grade plastics and PVC, are harder to recover. Even these plas-

FIGURE 3.2

Estimated Composition of the California Waste Stream by Weight

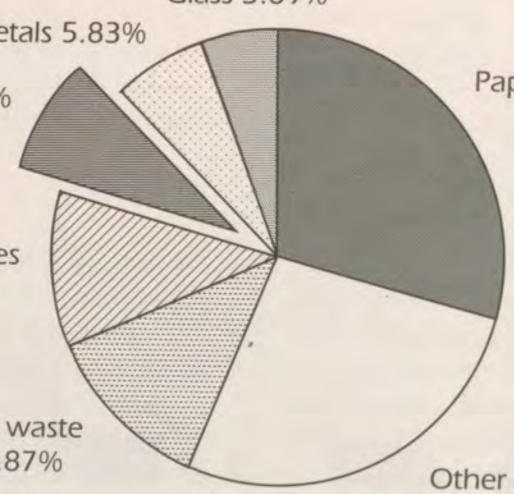
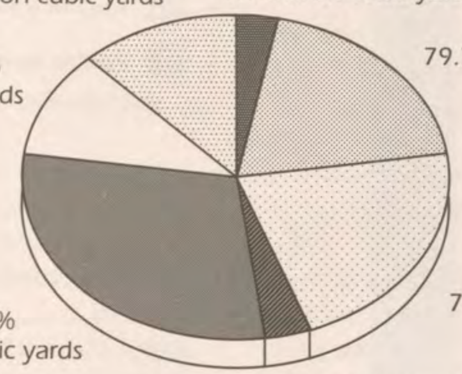


FIGURE 3.3

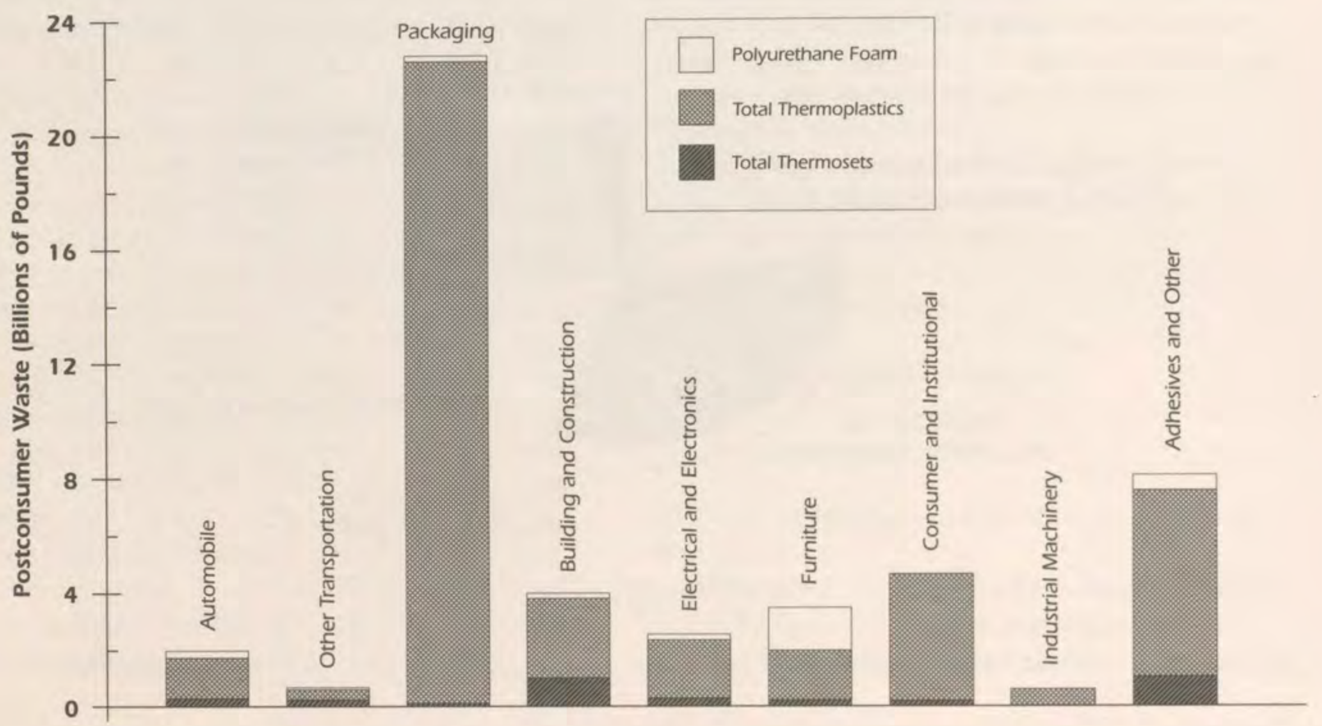
Volume of Discards in Landfills (1988)

Total Volume = 400 million cubic yards



Source: US-EPA

FIGURE 3.4
Postconsumer Plastic Waste Projections for year 2000



Source: Oak Ridge National Laboratory, May 1990

tics, however, are beginning to be recycled. PVC bottles, for example, are being transformed into multi-layered pipes and non-food containers.

The barriers to recycling in California, which are covered in detail in Chapter 7, include problems in separating plastics into basic resin groups, government regulations that hamper recycling, the high cost of recycling some types of plastics, the difficulty in collecting a steady supply of recyclable material, and an immature market for selling recycled plastics. Recycling of plastics is discussed more fully in Chapter 5.

With incineration, the volume of solid waste is reduced by burning it in the presence of oxygen. The remaining residue or ash is usually sent to the landfill. This process is controversial for three reasons.:

1) Properly designed facilities with adequate air pollution control devices are expensive.

2) Air emissions from inadequate incinerators have contained dioxin and furan, which are considered carcinogenic.

3) Some ash from incineration contains heavy metals and may produce toxic leachate in landfills. In California, incineration is opposed by many in the public and environmental groups.

Advocates of incineration say that the public has misconceptions and is not well informed about the latest developments in incineration technology. The industry claims that there are no dangerous emissions if the process is well designed and operated. The US EPA and AB 939 include incineration in their hierarchy of methods, and the US EPA found incineration to be the most effective method to reduce the volume of wastes.

The traditional method of disposal is landfill, and it accounts for 80 percent of municipal solid waste. It is also the focus of serious controversies:

- Maintenance and operation costs are constantly rising.

- Some landfills, both nationally and in California, are already polluting nearby land and are on the Superfund List of hazardous waste sites.

- People oppose the opening of new landfills even though California is rapidly filling up existing sites.

In an effort to review the volume of plastics in landfills, some resin manufacturers are developing degradable plastics.

After decades of creating durable plastics, chemists have now become reverse alchemists, developing plastics which degrade in different environments. As a result, six-ring beverage carriers that crumble, plastics bags that decompose, and medical sutures that dissolve are already available. Beginning in the late 1960s and early 1970s, research efforts began to develop plastics with enhanced degradability. This research has followed two distinct courses:

- The use of photodegradation, to increase the susceptibility of plastics to degrade by the action of the sun's ultraviolet rays. Plastics under the influence of ultraviolet (UV) radiation lose strength, become brittle, and may fall apart when stressed.

- The use of biodegradation, to promote the attack on the plastic by the action of bacteria. Biodegradation is generally considered to be the assimilation or consumption of substances by living organisms, but as applied to waste, it refers to microorganisms such as bacteria and fungi.

Unfortunately neither system is relevant to landfill decomposition. Biodegradation requires moisture and burial. Photodegradation requires the presence of UV radiation.

Even so, legislators in a number of states favor the production of degradable plastics. They have proposed bans on nondegradable plastic products ranging from egg cartons, tampon applicators and diapers to plastic grocery bags, liquor bottles and beverage rings that keep six-packs together. They also would require feasibility studies assuring that plastic products which represent a threat to fish and wildlife be degradable or recyclable.

The environmental groups declare that degradable plastics will not extend the life of landfills, do not solve the aesthetic problem created by litter, do not reduce the threat that plastics represent to wildlife, interfere with plastic recycling, can pollute the environment, and do not reduce the use of plastics.

Plastics manufacturers are banding together to fight for nondegradable plastics. Manufacturers advocate wider use of incineration and recycling, and fear their products will be less effective if they are more degradable.

Biodegradation of plastics in the landfill cannot be a realistic expectation because once a landfill is covered with soil, the amount of oxygen and water available for the degradation is very limited. (For a more detailed report on degradable plastics, please see Appendix 4).

Conclusions

Plastic wastes contribute significantly to the general problems of using landfill capacity and of litter on land and in the ocean. In addition, they create special pollution problems because of the danger that additives, such as cadmium and lead, might leach into soil and groundwater near landfills.

The methods for managing plastic wastes are essentially the methods for managing solid waste in general, and they fit into the hierarchy established by the Legislature in AB 939: (1) Source reduction, (2) Recycling and composting, (3) Incineration/Landfill.

Plastics are frequently used in inexpensive, disposable packaging and products, and packaging is the fastest growing market for plastics. Therefore, there is significant potential for source reduction and reuse as methods for managing plastic wastes.

Technically, incineration can play an important role in reducing the volume of plastic wastes, but it is less attractive economically and politically.

Chapter Four

Source Reduction of Plastic Wastes

Introduction

Reducing plastic waste generation really does attack the problem at the source. Unlike other methods that deal with waste after it has been generated, source reduction concentrates on prevention. It can be accomplished through changes in product design, manufacture, and in product use. These changes should result in use of less natural resources and less toxic substances, increased product life, and increased potential for reuse or repair. By reducing both volume and toxicity, source reduction efforts directly reduce disposal problems.

Volume Source Reduction

The first step in effectively reducing the volume of waste produced at the source is to select the best potential plastic product categories. The criteria developed for such selection can be general or specific, but the rationales behind the selection should include:

- ***Share of the product market.*** Market share has to do with the growth trends in a product category. For instance, the packaging category would be the best candidate for volume reduction because it shows a strong growth trend.

- ***Predominance of Disposable Products.*** This refers to items with lifetimes of less than one year that are frequently discarded into the solid waste stream.

- ***Consumer Preference Relative to Technical Performance.*** This is the rationale used to determine whether a product can be redesigned to reduce its volume. Consumer preference products — unlike engineering products that are designed to meet performance standards — offer more flexibility for redesign to reduce volume.

After narrowing the field of product categories, a more comprehensive analysis of each is required. For example, in the case where changing a color might decrease plastic waste in production, a further analysis might reveal that while color is trivial from a technical point of view, it is important for safety reasons.

Other criteria to be considered include the impact of reducing the volume of plastics on other materials and deciding whether source reduction is more important than recycling. In general, large source reductions are preferable to low recycling rates. There is, for instance, 85 percent less packaging material per pound of coffee in a brick pack made of aluminum foil/plastic laminate than there is in a conventional tin coffee can. As a result, repackaging will result in less plastic waste even though the recycling rate of the tin can is greater than of the brick pack.

The volume of plastic wastes can be reduced in a number of ways: substituting other materials for plastics in manufacturing, reducing the plastic used for given applications, using economies of scale in packaging, and the reusing of plastic products by consumers.

Substituting Materials

There is a general perception that substituting other materials for plastic packaging is beneficial and appropriate for a wide variety of products because in the past much packaging did not use plastic. Decisions to change packaging materials, however, should be made only after a careful analysis of the difference in costs, performance, energy consumed, and environmental impacts, according to studies by the US EPA and several others.

Redesigning Products

Manufacturers can reduce the amount of plastic consumed by redesigning the products. Some injection molders say that a 20 percent to 30 percent reduction in food container weights is feasible with improved designs. Weights also affect handling costs, especially transportation, in which lighter products have cheaper shipping prices.

Industries have already made some progress. DuPont Canada, for example, has sharply reduced wall thickness in some of its dairy food containers. The typical 8-oz. margarine tub had 22-mil (thousandths of an inch) walls in 1985. By June, 1990, it was 18 mils. A HDPE milk jug weighed 95 grams in the early 1970s. In 1990, a bottle of the same volume weighed only 60 grams. Plastic grocery bags that were 2.3 mils thick in 1976 have been reduced to 0.7 mils with the same strength and durability.

Reusing Products

Reuse is a powerful tool for reducing the volume of plastic wastes. This method provides an economic as well as an environmental incentive. With the increased use of plastics in the automobile industry, an easy-to-disassemble philosophy can be applied to make auto parts more reusable. General Motor engineers are already involved in the project of designing plastic auto parts easy to remove and reuse. Even disposable diapers can be designed to be washed and reused as many as 100 times.

Refillable containers also contribute to volume source reduction. Although there has been a trend away from refillable containers, some firms are using refillables. The Schroeder Milk Company of St. Paul, Minnesota, provides HDPE milk jugs that can be used 50 times. Once returned to the milk supplier, the container is sterilized, tested for contamination, and refilled by methods approved by the FDA. Encore of Richmond, California, has been providing refillable wine bottles for 15 years.

But the use of refillables is not limited to bottles. In India, cigarette lighters and ballpoint pens are refilled. In Central America, automobile battery cases are refilled with fresh lead and acid. Motor oil is sold in refillable glass bottles. In California, tofu is available in refilled buckets. Across the nation, shampoo and other health care and food products are sold in bulk, and customers are provided with refillable containers.

Toxic Source Reduction

The primary reason for reducing the toxicity of plastic wastes is to decrease the health risks posed by their incineration or disposal. While some resins themselves pose such risks, usually more risks come from materials added to the resins.

The two main toxic additives are cadmium and lead, but some other additives, such phthalates, also cause toxicity. Plastics account for about two percent of all lead and 36 percent of all cadmium discarded. Cadmium is added for orange or yellow coloring and lead for flexibility. They have caused toxicity in the leachates from landfills and in the ash from incinerators.

Finding toxic-free substitutes for these additives requires a careful evaluation of performance of the substitutes in the final product. Basically, this selection is determined by manufacturer's ranking of the importance of certain attributes, such as chemical compatibility, hue, light and heat fastness, intensity, flexibility, and electrical insulation. One manufacturer, for example, can produce colorants free of heavy metals, but it can make the plastic unstable in light.

Many colorants are not used as substitutes because of their chemical incompatibility with polymer solvents, resins, and end use products. For example, some pigments may not be used in PVC products because of their sensitivity to acid attack. Other colorants do not perform well under the high temperatures used during the processing of plastics. A colorant-polymer combination that is suitable for indoor applications may be ruled out for exterior applications. Thus, the substitutes appropriate for replacing pigments that contain lead and cadmium should be selected in accordance with the processing conditions and color requirements.

Lead is used in heat stabilizers, flexible PVC, and electric insulation. Some of the heat stabilizers containing lead have been replaced, such as those used in pipes and music records. Replacement of lead in flexible PVC and electric insulation, however, depends on costs and reliability of the substitutes. For example, lead can be replaced in flexible PVC products such as shoes and sandals, but it is difficult to replace lead in insulation products such as power wiring, cords and connectors because of the unique properties of lead as insulator and heat stabilizer.

Other plastic additives that are candidates for study include phthalates used as plasticizers in PVC and flame retardants composed of antimony oxide. The potential for reducing the use of these additives in plastics requires complex evaluation and intense investigation.

Despite all the difficulties, several companies are introducing new toxic-free formulations. For example, Em Industries Inc. of Hawthorne, New York, introduced in 1991 a new line of pigments that are non-toxic. Akzo Engineering Plastics Inc. is marketing a non-halogenated colorant.

Source Reduction Studies

The US EPA has identified only four studies related to volume reduction of plastic materials. Two were done in the U.S. and two in Germany. Although all four studies provide useful conclusions for direct substitution of other materials for plastic, none of them presented a comprehensive analysis of all the variables involved. For example, none of the studies evaluates consumer-related issues (safety and utility). A variety of organizations including US EPA, the Conservation Foundation, the Tellus Institute and Battelle are working to resolve these drawbacks. US EPA, for example, granted a $850,000 research contract to Battelle for developing a methodology in life-cycle analysis, which is the study of the environmental and economic impacts of products from raw material to disposal. The Board has followed the development of life-cycle analysis and is considering funding projects pending the completion of the US EPA study.

A comprehensive source-reduction assessment must consider the range of environmental releases produced by the development, manufacturing, and transportation of raw materials. The study should also take into consideration air, water and solid waste profiles of the processes involved, as well as the solid waste management.

Methods to Promote Source Reduction

Over the last 20 years, several methods have been attempted to promote source reduction, including educational efforts, industry research and development, and government actions. The results have been mixed:

Educational Efforts

Changes in product and packaging design mean nothing if consumers ignore them. The purpose of public education programs is to show consumers the possibility for individual action and make them feel that such action is important. In order to motivate consumers to change patterns of behavior, a series of educational programs must be established.

Without such effort, consumer education programs will meet with the mixed success experienced in the past. In 1986, for example, the Pennsylvania Resource Council's Environmental Shopping Campaign used labels and lists of desirable products to inform consumers about source reduction. The council found that general concepts seemed difficult for

TABLE 4.1

Some Easy Ways for Consumers to Reduce the Flow of Plastic in the Waste Stream

- Use fabric or string-net sacks at the market, a method used successfully in Europe and many other countries.
- Re-using plastic sacks several times, for wrapping sandwiches, storing leftovers or freezing vegetables.
- Buying food in bulk or joining food co-ops to avoid excess packaging.
- Substituting alternative products for minimally convenient products. Replaceable blades, for example, can be used in place of disposal razor blades.
- Suggesting plastic collections when schools propose paper collections. Also, seeking out recycling operations that accept plastics.
- Suggesting recycled plastic items, such as speed bumps, picnic tables, decks, etc., when the town is planning to build parking lots, parks, or recreation areas.
- Buying household products in concentrated form and packaged in polyolefin pouches rather than bottles.

consumers to comprehend and that promotion of individual items was more promising.

Groups of consumers can have direct influence on the design of products and packages by manufacturers. One example would be a seal or certification permitted by the state to indicate that a product or package meets certain requirements for source reduction. The groups could participate in the establishment of the requirements and then educate their members to look for and demand the seal or certification at the time of purchasing.

Industry Research and Development

Industry research to find non-toxic substitutes for additives and to cut the volume of products and packaging while increasing durability should be promoted, developed and rewarded. Industry should be given incentives to give higher priority to developing more durable, reusable products and compact packaging.

Government Actions

Government actions can discourage the use of nondurables and over-packaged products through product bans, taxes, tax credits, loans, grant awards, contracts, and education programs. Government procurement programs can favor more durable, longer lasting products. Procurement regulations could also prohibit buying a disposable item to replace a durable item. Government can also mandate standards for durability and repairability of consumer goods.

Regulatory measures that encourage or directly force substitution for plastics have been more widely employed in Europe. Italy has banned the use of non-biodegradable packaging. Denmark, Netherlands, and West Germany all have fairly broad authority to restrict packaging methods.

Taxes have also been imposed to achieve source reduction goals. The taxes range from volume-based user fees for disposal to product-specific taxes.

Some taxes, however, are erroneously classified as source reduction measures because they do not directly encourage consumers or industries to reduce the amount of waste they generate. These taxes include per ton surcharges on waste disposal and taxes on frequently littered products. While these taxes are not direct source reduction measures, they do generate revenue that can be used for recycling or source reduction programs and research.

One taxing mechanism that has received increasing attention recently is a graded tax on all packaging materials. Legislation to establish such a variable-tax system has been introduced in Massachusetts and New York. If passed, consumers would pay a three-cent tax on certain rigid and semi-rigid containers used for non-food products and fast food packaging. A packaging tax board would be set up to determine credits and exemptions for different containers based on reusability, recyclability, and recycled content.

The rationale behind a variable tax is to make the price of a product reflect the avoided environmental and economic costs of disposal. Critics of this tax argue that a difference in one cent to three cents is not enough to cause consumers to change their shopping habits, and therefore does not result in source reduction. But others point out that this per-package tax may provide a significant incentive for manufacturers to use recyclable packaging or recycled material.

Another tax-like method to encourage source reduction and recycling is an Advanced Disposal Fee (ADF), which is levied at the point of sale to cover the cost of recycling or disposing of the material. The Board's Planning and Assistance Division is analyzing different options for ADF on packaging materials.

The Board may assign fees to packaging products with a credit system for operations that use recycled-content materials, including plastics. The fees collected would be used to support the collection infrastructure, for grants to businesses to retool or re-equip for recycling, and to industry to buy products.

Deposits on PET beverage containers have been the most successful strategy in increasing plastics recycling and promoting source reduction. To the extent that deposits encourage people to return containers for reuse, they are an incentive for source reduction. The deposits, however, can actually act as a disincentive by discouraging manufacturers from introducing better source-reducing packaging.

Scale deposit systems that place a lower deposit on refillable or recyclable containers are one way that bottle bills promote source reduction. While most deposit systems do not single out plastic containers, scaled deposit laws that place a higher deposit on larger containers can have a direct impact on the use of plastic if they encourage consumers to buy one- and two-liter PET bottles.

Conclusion and Recommendations

Conclusion

Education is one of the most important tools to promote source reduction. With source reduction in mind, manufacturers, retailers, and customers are able to make environmentally sound decisions. Thus, while manufacturers design less toxic and more durable and reusable products, consumers are shown how to modify their purchasing decisions.

Government actions play an important role in promoting source reduction. This is done by creating incentives/disincentives toward the procurement of certain products. Bans, taxes, and other sanctions are sometimes proposed on overpacking and toxic materials. Incentives such as grants and loans can be provided to companies involved in effective source reduction.

Substitution from plastics requires careful consideration of costs, performance, environmental impacts, and customer-related issues such as safety and utility. In the same way, substitution of additives to reduce toxicity should be carefully considered because the alternatives might be scarce, expensive, chemically incompatible, or of poor performance.

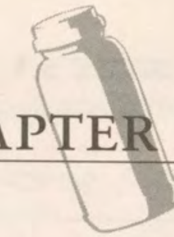
Recommendations

1. The California Integrated Waste Management Board will develop and maintain an information clearinghouse on source reduction issues. The clearinghouse will collect and disseminate information on existing programs, existing and current research, and other information that will assist the commercial sector and local governments in pursuing source reduction efforts.

2. Heavy metals in packaging should be reduced and eventually phased out. A study is needed to determine a reasonable time frame for the reduction and to suggest methods to facilitate research in developing alternatives to heavy metal additives.

3. Because source reduction is a relatively new and still developing field, the grants programs would help local governments and non-profit organizations develop source reduction programs and activities.

4. Academic curriculum of elementary and secondary schools should include source-reduction introductory courses. In higher education, courses in source reduction technology should be added to engineering curriculum, and grants for research would help in the development of new source reduction methods.



CHAPTER FIVE

Plastics Recycling

Introduction

Until recently, plastics in the municipal waste stream have received little attention; they have simply been buried or burned. But the rising costs of landfilling, concerns about the health implications of incineration, and public's increasing concern with the environment have prompted many states to seriously consider recycling.

Recycling is defined by the Board as the process of collecting, sorting, cleansing, treating, and reconstituting materials that would otherwise become solid waste and returning them to the economic mainstream in the form of raw material for new, reused or reconstituted products that meet the standards necessary to be used in the marketplace.

This chapter discusses the collection, separation and reclamation of postconsumer plastic wastes. Chapter 6 discusses the most important, but often overlooked, portion of the recycling process — the markets for recycled plastics.

Curbside Collection of Plastics for Recycling

Efficient and effective collection of postconsumer plastic wastes is one of the the most important steps to ensure the success of a recycling program.

Curbside programs have become an extremely popular way to collect recyclables, and a growing number of communities are relying on these programs to meet mandated diversion goals required in many states. There are already more than 2,710 curbside collection programs in operation nationally, of which 800 are collecting plastics. The majority of curbside programs that collect plastics are in four states: New Jersey, Wisconsin, Pennsylvania, and California.

As shown in TABLE 5, the number of curbside collection programs in California that accept plastics has increased dramatically in the past few years. A review of a database of curbside collection maintained by the Department of Conservation's Division of Recycling indicates that almost all of the state's curbside programs collect PET, and that a growing number are collecting HDPE and other plastics. Of the 280 California curbside collection programs surveyed in 1991 by the Division of Recycling, 269 accepted PET, 122 accepted HDPE, and 69 accepted other types of plastic. (See Appendix 2).

Curbside collection of plastics and other recyclables generally involves the use of a specially designed truck that picks up recyclables separated by the consumer. Trucks are often compartmentalized for separating recyclables to facilitate the sorting processes at the Materials Recovery Facilities (MRFs). Most MRFs also separate mixed waste. Some vehicles are equipped with compressors and grinders exclusively used for plastics.

Curbside programs are operated by local governments, private industry, and non-profit organizations. They are an interesting recycling option because they require involvement from participants without offering any direct financial incentive. Citizens participate because it is convenient or because they believe they are making a personal contribution to the solid waste problem. Some programs are mandatory.

Although curbside collection programs have the potential to divert the most significant quantities of municipal solid waste (MSW) from disposal, there are drawbacks. They are difficult to implement in multifamily dwellings, they increase net costs to municipalities, and it is inconvenient to segregate plastics from other wastes.

Analysis and comparison of existing programs are difficult because there are many variables that can affect the performance of the program. However, the recovery rate in pounds per household per year (lbs/hh/yr) is the preferred variable for measuring a program's success.

Attempting to use the rate of participation to measure a program's success in collecting plastics is deceptive. For example, San Francisco's curbside program services 70,000 households, while Phoenix's program services only 11,000 households. However,

TABLE 5.1
Curbside Collection Programs in California, 1989-1991

	9/1989	12/1990	8/1991
Total number of programs	130	235	280
Programs accepting PET	82	176	269
Programs accepting HDPE	1	56	122
Programs accepting mixed plastics	0	41	69

Source: California Department of Conservation, Division of Recycling.

the plastics collection program in Phoenix can be considered more successful because its recovery rate (33.5 lbs/hh/yr) is greater than the recovery rate in San Francisco (1.3 lbs/hh/yr).

Other primary factors affecting the performance of curbside collection programs include the frequency of collection, the kind of truck, the type of material collected, and the type of collection container. Many cities in California report problems in the size, convenience, and price of the container, as well as scavenging.

To assist in the analysis and comparison of curbside collection programs, Resource Integrated Systems, Ltd. (RIS), prepared a study for the RIS's Council for Solid Waste Solutions in 1990 to identify criteria likely to maximize the recovery of postconsumer plastics. Factors identified in the study included:

- multi-material curbside collection
- mandatory separation requirements
- use of household set-out containers
- collecting a wide variety of plastics
- weekly collections
- effective promotion and education

Other factors identified by the study that increased the efficiency and cost-effectiveness of collecting plastics in curbside programs included:

- collection of recyclables on the same day as refuse collection
- commingled collection of loose container materials
- use of large-capacity, specially designed trucks
- one-person collection crews
- use of bags as a set-out container for mixed recyclables
- use of single container, as opposed to multiple containers
- use of a box-shaped container rather than a round container
- use of larger set-out container

Combining these and other variables in the analysis and comparison of programs within California, with other states and other countries is extremely difficult and laborious. Computer data based programs are not flexible and sensitive enough to properly evaluate the wide range of collection options available. Adding to the difficulties is the lack of uniform information or even standard terms within the plastics industry.

As a result, this report analyzes and compares programs based on the seven primary factors affecting program performance in terms of recovery levels. Most of the figures are taken from the 1990 RIS study.

Program Type

Mandatory programs apparently perform better than voluntary programs. The RIS survey of 18 national curbside collection programs (three mandatory) revealed that mandatory programs collect 70 more pounds of all materials per household per year than voluntary programs. However, there are exceptions, even in this relatively small RIS study. The voluntary San Francisco Program recovers the same amount of total recyclable materials (332 lbs/hh/yr) as the mandatory West Warmick, Rhode Island, program. These two programs are very similar except for the number of households serviced. While San Francisco services 70,000, West Warmick only services 8,900 households.

Container Type

In any curbside collection program, it is important that the size of the household container be adequate. In some cases, convenience and customer's preference are also to be considered. A program in Arlington Heights, Illinois, used an 18-gallon rectangular bin, and had one of the highest plastic recovery rates (23.5 lb/hh/yr) of all the programs surveyed by RIS. In contrast, the Palo Alto program in California reports the lowest plastic recovery rate (0.5 lb/hh/yr) of the study, using burlap bags. Buckets and bags are associated with garbage. A rectangular bin is associated with recycling. In general, a rectangular bin is the preferred option.

Material Type

PET has been the target for many curbside collection programs in the United States. This material is highly consumed, and the easiest plastic to identify and to reprocess.

In France, almost all of the plastic recycling activity is concentrated in PVC. Nearly all plastic beverage bottles in France are made of this resin because they are big consumers of non-carbonated water. In the recovery from the household stream, glass and PVC bottles are collected in the same container, but the people are asked not to put PET bottles in these banks.

Collecting the widest possible range of plastics helps to maximize the recovery of postconsumer plastics. For example, the curbside collection program in Portland, Oregon, collects HDPE, LDPE, PET, and other rigid plastics. The recovery rate is 8.6 lb/hh/yr. After collection, the materials are taken to Wastech in Portland for processing, and the plastics are sold to Partek.

Frequency Type

Important studies, such as the Massachusetts-Rhode Island study of 41 programs around the world, have shown that increasing collection frequency usually results in higher participation rates and higher recovery rates. However, the sample data made it difficult to derive a direct relationship between the frequency of collection and rate of recovery.

Promotion and Education

It is universally accepted that both effective promotion and public education are essential to successfully develop recycling programs. The effects of increasing promotion and information about plastics wastes are best demonstrated in Japan.

One of the main purposes of the Japanese programs is to eliminate misunderstandings about plastic wastes among the general public. In order to achieve this goal, many pamphlets, guidebooks and other regular publications are distributed to the public. They also lend films free of charge. The programs strive to inform the public so that citizens understand the issues and know how they can help participate. As part of the program, cities in Japan exhibit samples of reclaimed plastic products to support the use of recycled plastic and to emphasize the importance of recovering plastic wastes.

In the United States, the Mecklemburg County program in North Carolina (8.8 lb/hh/yr recovery rate) is a good example of a well promoted plastics recycling program. The county has received a lot of support from private organizations. Pepsi, for example, donated money for promotion, and Coca-Cola donated a granulator. The National Association for Plastic Container Recovery (NAPCOR) also helped the county to get quotes from plastic buyers. In the Mecklemburg program, recyclable material is taken to a Materials Recovery Facility operated by Fairfield County Redemption in Charlotte, which is designed to receive and separate commingled materials. At Fairfield, the PET is baled separately and then sold to Wellman.

The Napeville Area Recycling Center (NARC) is another good example of promoting a program. In January, 1987, NARC joined with four local recycling centers and Eaglebrook Plastics to begin the collection of HDPE. To promote this program, NARC encour-

aged people to recycle by advertising in newspapers, direct mail, and signs in the milk departments of all grocery stores. A random survey of recyclers was also conducted to determine if residents would be willing to recycle plastics. NARC is enthusiastic about the success of the HDPE recycling program and is assessing whether to add PET containers to the program.

Centralized Facilities for Collecting Plastic Wastes

These are centrally located collection depots that do not pay for recyclable materials. These drop-off centers are used alone or in conjunction with a curbside collection program. In general, they appear to be more effective in rural areas, where curbside collection programs are limited or do not exist.

The factors affecting the performance of drop-off collection programs correspond closely to those considered in the curbside collection programs. Some of these factors are the population served, number of customers, hours of service, number of sites, type of processing, contamination level, and marketing locations.

Some communities offer centralized drop-off facilities for recyclables in shopping centers and other convenient locations. In Holland, supermarkets are taking an active role in source segregation of both paper and plastic. The supermarkets are using their purchasing power to require their suppliers to include only packaging materials suitable for recycling. They are also discouraging glued paper labels, which complicate reprocessing, and are starting to require the use of the same polymer in the pallet wrapping. Some governments in Europe have required supermarkets to take back any container sold. While not all containers are returned, the regulations provide an incentive to sell recyclable containers.

Usually, drop-off centers collect a variety of recyclables deposited by type into separate receptacles.

Germany has also been very active in developing different collection schemes. In one area of 400,000 inhabitants, a multi-bin separation system has been established, in which customers place all the collectibles, except PS.

In San Diego, plastic bag drop-off depots at supermarkets are growing. In San Diego County, 163 stores are participating, according to a recent survey conducted by the San Diego Department of Public Works (DPW). The list of stores includes Ralph's, Thrifty's, Lucky's, and Von's chains. One store chain alone, Ralph's, collects 22 tons per month, according to DPW.

In Canada, private companies are also participating in the collection and development of plastics recycling technologies. PCL & Eastern Packaging of Saint John in New Brunswick had boxes in 347 stores to collect grocery bags in 1990. After baling, the company pays $0.20 per pound for the material. Other large manufacturers of plastic bags, such as Sonow Products, Mobil Chemical, and Vanguard Plastics are involved in pilot programs to recover plastic bags from the waste stream.

A growing number of centers are beginning to collect polystyrene. For example, the National Polystyrene Recycling Company (NPRC) is accepting polystyrene food service waste collected from school districts and other large institutional settings. The San Diego-based franchise of Mail Boxes Etc. (MBE) just announced that it is accepting PS "peanuts" at all of its stores. MBE reports savings of up to $26,000 by reusing peanuts brought in by consumers. This program is part of a nationwide initiative to recycle PS packaging. The program is implemented by MBE and the Plastic Loose-Fill Producer's Council. The Plastic Loose-Fill Producer's Council is a consortium of five PS producers, which include Free-Flow Packaging Corporation of Redwood City, California.

Other pack-and-ship operations that are part of the collection process are Associated Mail and Parcel Centers, Pak-Mail and the Packaging Store.

There are more than 482 collection sites in California. The Association of Foam Packaging Recyclers is now recovering more than 15 million pounds of polystyrene foam nationally, according to Dow Chemical Company.

The City of Palo Alto has one of the most successful programs for collecting PS foam and protective packaging. The products are received at four drop-off sites in the city. The collection of this material saved the city some $7,000 in avoided disposal costs.

Other cities with polystyrene drop-off centers include Santa Monica, Burbank and Santa Cruz.

Buy-Back Collection Centers

Buy-back collection centers are depots where people are paid for recyclable materials. Beverage Industry Recycling Programs (BIRP) are an example of this collection method.

BIRP centers, operating in 17 states, are sponsored, at least in part, by the beverage industry. There are two models: the Arizona model, which is a system of multi-material buy-back centers owned and operated by a statewide organization; and the Kentucky version, which is a promotional system for privately owned and operated buy-back centers and other recycling operations. Many BIRP centers have been developed to interest children in recycling. Attractive names are given to the machines; the plastic bottle shredder, for example, is called "Chewbot-L".

Private companies, such as Geo Resources and Poly Pack America Inc. in Los Angeles, are also actively participating in buy-back programs. Geo collects and reprocesses discarded plastic envelops from grocery stores, drug stores, home improvement chains and department stores. Poly Pak then uses the recycled resin to make plastic bags, plastic mailing envelopes, and multi-layer plastic film bags for the lawn and garden industry. The customers receive credit or payment from Poly Pak for envelopes returned for recycling.

The California AB 2020 program is one example of a buy-back collection program. The program consists of 2,400 sites established to collect soft drink containers under California's Redemption Law. The 1990 RIS study estimates the program to cost $524 per ton of material recovered and $7.23 per capita annually, not including the life-cycle costs of recycling.

Buy-back programs offer the possibility of collecting relatively pure resins with little cost to government agencies. However, the inconvenience for consumers, who must store and transport recyclables, dilutes the effectiveness of this alternative.

Reverse Vending Machines

Reverse vending machines are automated buy-back centers. These machines allow consumers to insert empty PET soft drink bottles, then it verifies the shape and size of the bottle, and dispenses cash, a discount coupon or token that can be redeemed at the adjacent grocery store. Some reverse vending machines include compactors or granulators to immediately reduce the volume of the PET bottles.

Supermarkets in Ferrara, Italy, are experimenting with reverse vending machines to recover both PVC and PET. The machine dispenses receipts usable for discounts in the stores and uses sophisticated presses to reduce the size of the collected material. There are no technical or quality problems in the recycling of PET. Also the recycling of laminated milk containers is very successful.

In Sweden, various types of reverse vending machines have been tested. In the trial, return yields of 60 to 70 percent were achieved with a 0.5 SKr deposit (9 cents U.S.), but that country is considering increasing the deposit to 1.5 SKr (26 cents U.S.) to obtain higher yields.

In the United States, reverse vending machines are used to collect PET beverage containers both in states with and without deposit programs. A number of local governments in California allow private companies to operate these machines within their communities, although most of these communities do not rely solely upon this collection method. While reverse vending machines are effective at collecting a homogeneous supply of materials at little or no cost to governments, they capture only a small percentage of recyclable plastic bottles. Additionally, some machines break down regularly and frustrate consumers who may already have gone to the some trouble to collect, store, and transport bottles to the machine.

Preparing Plastic Wastes for Recycling

After plastic wastes have been collected, either at curbside or a central location, the recyclable plastics need to be separated from other recyclable materials. Then, the recycling program or plastic reprocessor separates the different types of recyclable plastics to maximize the markets for the material. Most postconsumer plastic wastes collected in both California and throughout the United States are separated manually, creating a significant cost that hampers the cost-effectiveness of postconsumer plastics recycling.

Until recently the preparation of plastics for recycling was relatively simple because most collection programs only accepted PET beverage containers. These bottles could be easily identified by their distinctive shape and product type by both the public and recycling center operators. Because centralized collection facilities were the primary collectors of PET, the facility's operators or the public simultaneously separated and sorted the beverage containers by putting them into a collection bin designated for PET beverage containers. Some centers also separated green colored PET bottles because of the higher market price for clear bottles. When sufficient material was collected, the center operators would reduce the density of the bottles by baling them so that the material could be cost effectively shipped to domestic or overseas reprocessors.

In recent years, the proliferation of curbside collection programs and the growing political pressure to recycle other plastics have increased the complexity of preparing plastics for recycling. For example, many curbside collection programs collect commingled recyclable containers in a single collection container and separate the different material types at a central facility, such as a materials recovery facility (MRF). Currently many MRFs rely completely on manual separation of different materials using a tipping floor, table, or conveyor belt. The speed and efficiency of this type of separation are dependent upon how the system is operated. For example, a survey of manual plastic sorting rates at MRFs conducted by the Council for Solid Waste Solutions showed rates ranging from 73 to 554 pounds per worker per hour. Factors that affect separation rates include how many materials are included in the program, how many materials each worker is separating, and whether the workers are removing non-recyclables (negative sort) or recyclables (positive sort) from the separation area or line.

Although manual separation is used by many collection facilities, a growing number of MRFs are using automated techniques to separate plastics from other recyclable material. These include magnets to separate out metals, vibrating screens to separate different size containers (e.g. aluminum cans vs. PET bottles), and air classifiers that blow lightweight materials, such as plastic and aluminum, from heavier materials. Some facilities also use eddy-current separators, which apply an alternating magnetic field to aluminum cans and is used to separate them from non-metallic plastics. Despite considerable initial costs, automated separation equipment generally reduces the costs of separating plastics from other materials if plastic volumes in excess of several hundred pounds per hour are being handled.

While manual separation of recyclable materials is relatively straightforward, the manual sorting of different types of plastics is more difficult. Although some reprocessors are able to buy bales of mixed plastic bottles, many collection programs need to perform at least some sorting of their plastic waste by resin type and color to recover the costs of collecting plastics. Although plastic bottles such as PET beverage containers and HDPE milk jugs may be readily identifiable on a manual sorting line, other types of plastic bottles are more difficult to classify by resin type. For example, clear PVC and PET bottles used in a number of food products may look nearly identical. A very small number of PVC bottles accidentally sorted with PET bottles, however, can ruin the marketability of the material to reprocessors.

In an effort to assist collection programs in sorting plastic bottles, a number of states including California require bottle manufacturers to imprint a resin identification code developed by the Society of the Plastics Industry on plastic bottles. Most collection programs report that the sorting of plastic bottles is done faster by identifying the product type of the bottle than locating the small codes. Presently these codes are primarily used by collection programs to assist the public in identifying what bottles are accepted by program.

While sorting plastic bottles is difficult and expensive, separating other plastic wastes, such as plastic films, foam padding, and small appliances, is beyond the ability of most collection programs. Presently most collection programs only collect easily recognizable bottles such as PET beverage containers and milk and water HDPE jugs. According to a 1991 survey of California plastic collection programs contracted by the Board, only a limited number of communities collect other types of plastic bottles as part of their curbside collection program, while only a handful of curbside programs — in cities such as Gilroy and Burbank — accept other types of plastics, such as polystyrene and plastic films.

A number of new technologies are being developed and commercialized to automate the sorting of plastics bottles. Most of these technologies involve aligning single bottles on a high-speed conveyor past a scanning device and ejector which detects some identifying mark or inherent property of the bottle or resin. The most developed technologies to date have involved the separation of PVC bottles from other types of bottles. Two companies are selling systems that detect and sort whole PVC bottles from other types of bottles. Both the ASOMA Instruments Inc. (Austin, Texas) and National Recovery Technologies (Nashville, Tennessee) systems use X-ray fluorescence to detect the chlorine atoms found only in PVC resin. Magnetic Separation Systems Inc. (Nashville, Tennessee) recently began marketing a complete modular system that can sort PVC, green and clear PET, polypropylene, and various colors of HDPE bottles at a single line capacity of 1,250 pounds per hours or multiple line capacity of up to 5,000 pounds per hour.

Other technologies being examined include systems that separate bottles using optical sensors that sense the color, shape, or opacity of the bottle. Rutgers University has investigated using the bar codes used by grocery store scanners as a method of detecting the resin type of different bottles. This approach was hampered by a significant number of bottles with missing bar codes and the difficulty in maintaining an accurate database of the resins used for each product. A system recently proposed by Eastman Chemical Company (Kingsport, Tennessee) would involve the use of optics to read a molecular marker that would indicate the resin used in the plastic container. This system would involve considerable cooperation among resin producers and bottle manufacturers, and is unlikely to be adopted in the near future.

Reclamation Technologies for Plastic Waste

After plastic recyclables have been sorted by resin type, reprocessors clean, process and melt them. The reclaimed product, in either flake or pelletized form, then becomes the feedstock in the manufacture of new products.

Some plastic resins are not yet sufficiently valuable in recycled form to make generic recovery economical. These low-value recycled resins are recovered in mixed (commingled) form, and an increasing number of products is now manufactured from commingled plastics.

Polyolefin Reclamation

This technology is used in recovering resins from HDPE (milk jugs), LDPE (bread, dry cleaning, and shopping bags), LLDPE (bacon and wiener wraps), and PP (bottle caps and snack wraps). Polyolefins include both rigid and film forms. The separation of these two forms in the reclamation process is important for assuring a more marketable recycled pellet.

In general, the basic process is to unbale and shred the material, then prewash, granulate, sort, wash, dry, and regranulate. Typical infeed mixtures in Western Europe contain 65 percent polyolefins, 15 percent PS, 10 percent PVC, and 5 percent other plastics. FIGURE 5.1 shows the PolySource reprocessing developed by AKW of Germany.

The performance and color of the recycled resin depends on the infeed materials. If only milk bottles are used, the reclaimed resin is of such a good quality that it can be blow molded into another clear bottle (which cannot be used for food). However, if a mixture of HDPE materials is used, the resultant resin is grey and is only suitable in injection-molded products (not for plastic bags). Close monitoring and running materials in batched lots is recommended for the highest quality recycled resin.

PET Reclamation

Most commercial recycling technologies for PET are based on methods developed by corporations such as Goodyear or DuPont. Processes may differ in some aspects, but the general tendency is to recover the entire container in order to make the separation by color easier. Colorless PET is more saleable than green or mixed colors. Here is the process, in general:

- Granulation to a uniform particle size.
- Air classification of the dry components.
- Water/solvent rinse to remove adhesives and label fibers.
- HDPE separation in a flotation chamber. (HDPE floats, while PET and aluminum sink)
- Complete drying of PET and aluminum.
- Separation of aluminum from PET using a high voltage electrode. (FIGURE 5.2 illustrates the processing flow).

Companies reprocessing PET include Enpivco, Nycon, Procedyne, Puretech, St. Jude Polymer, and Wellman. They produce more than 125 million tons of processed PET annually. Wellman is the leader, producing more than 100 million tons per year.

Commingled Plastics Reclamation

The process of recycling more than one type of plastic in the same unit is called commingling, and consists of these major steps:

1. Coarse sorting of ferrous and nonferrous metals.
2. Granulation and pulverization.
3. Refined separation of ferrous and nonferrous.
4. Air classification.

FIGURE 5.1

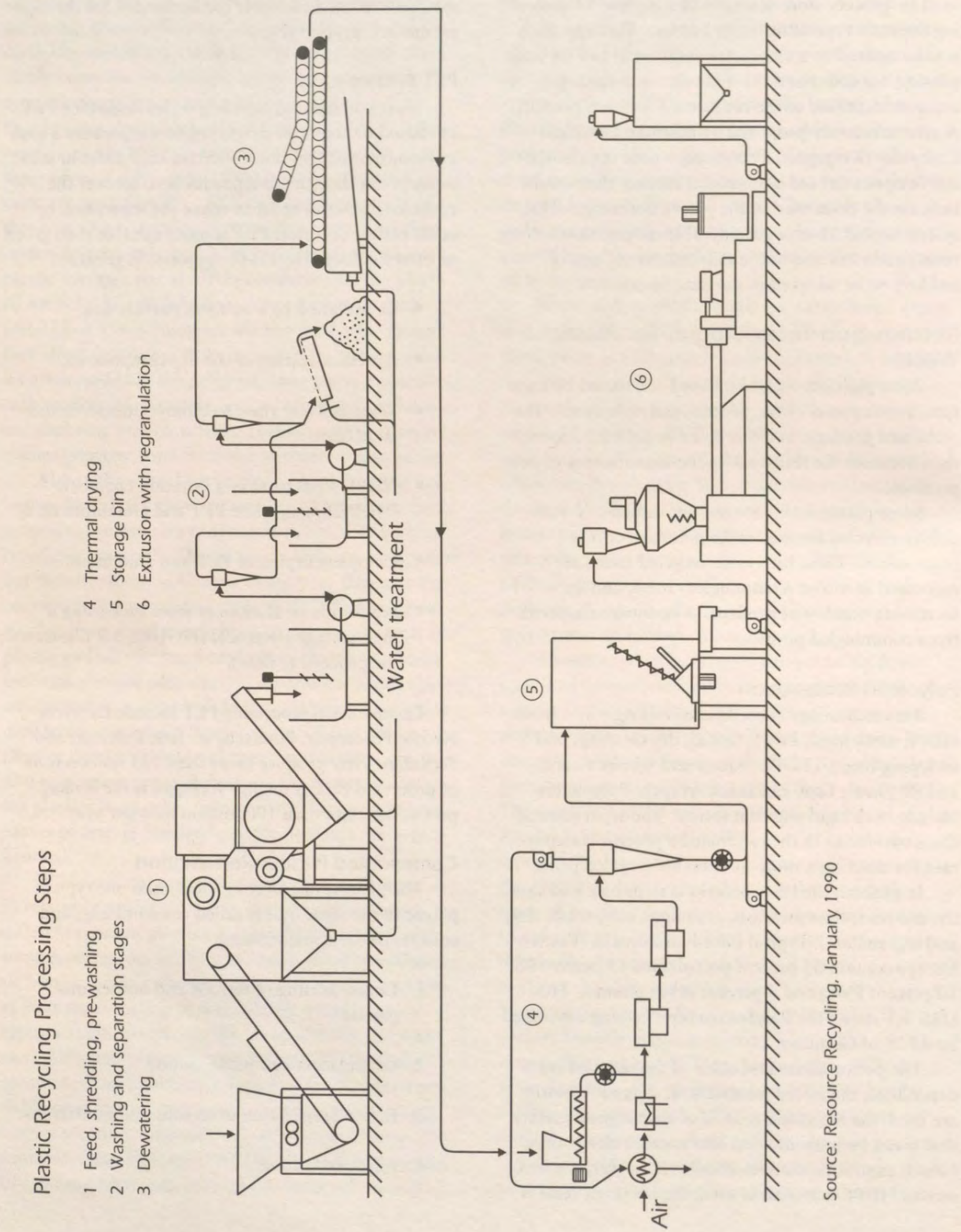


FIGURE 5.2

Feed Rates and Separation for PET Recycling Process

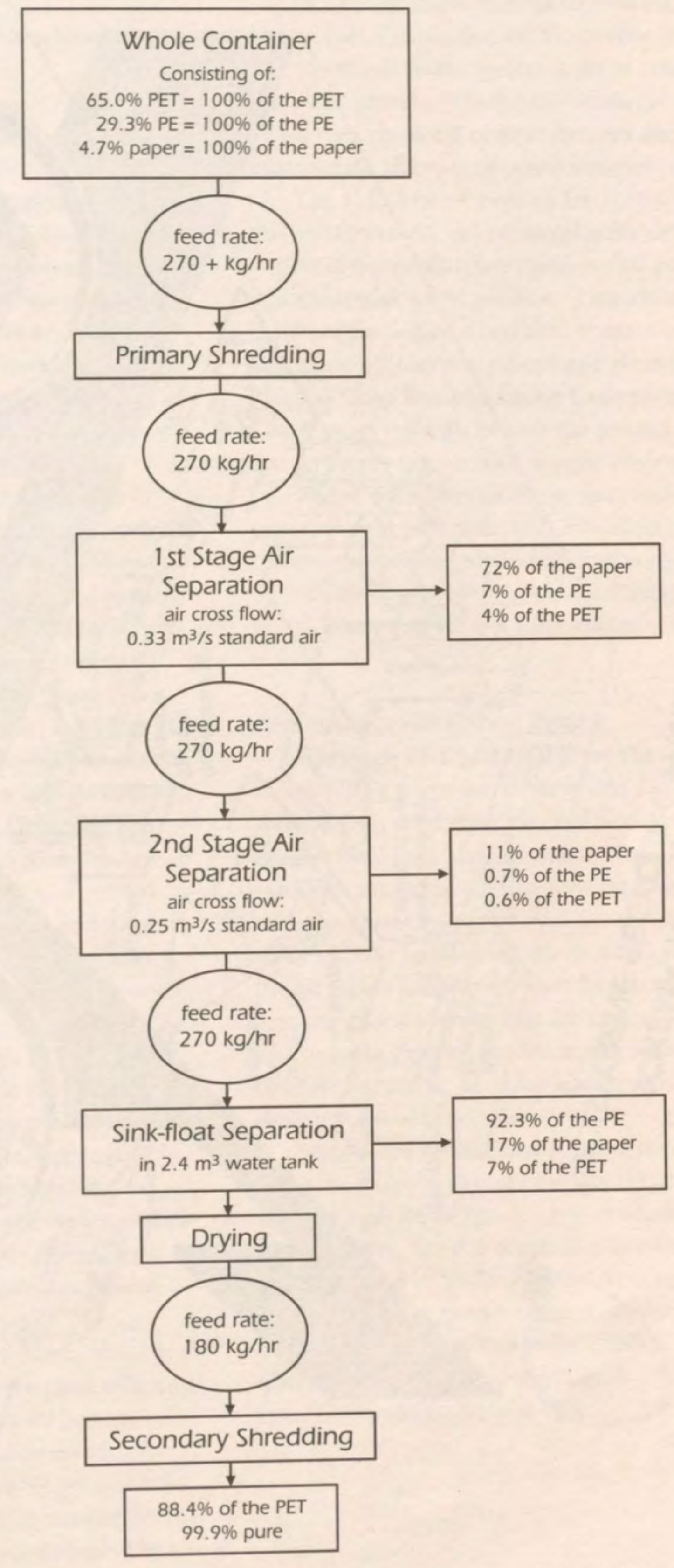
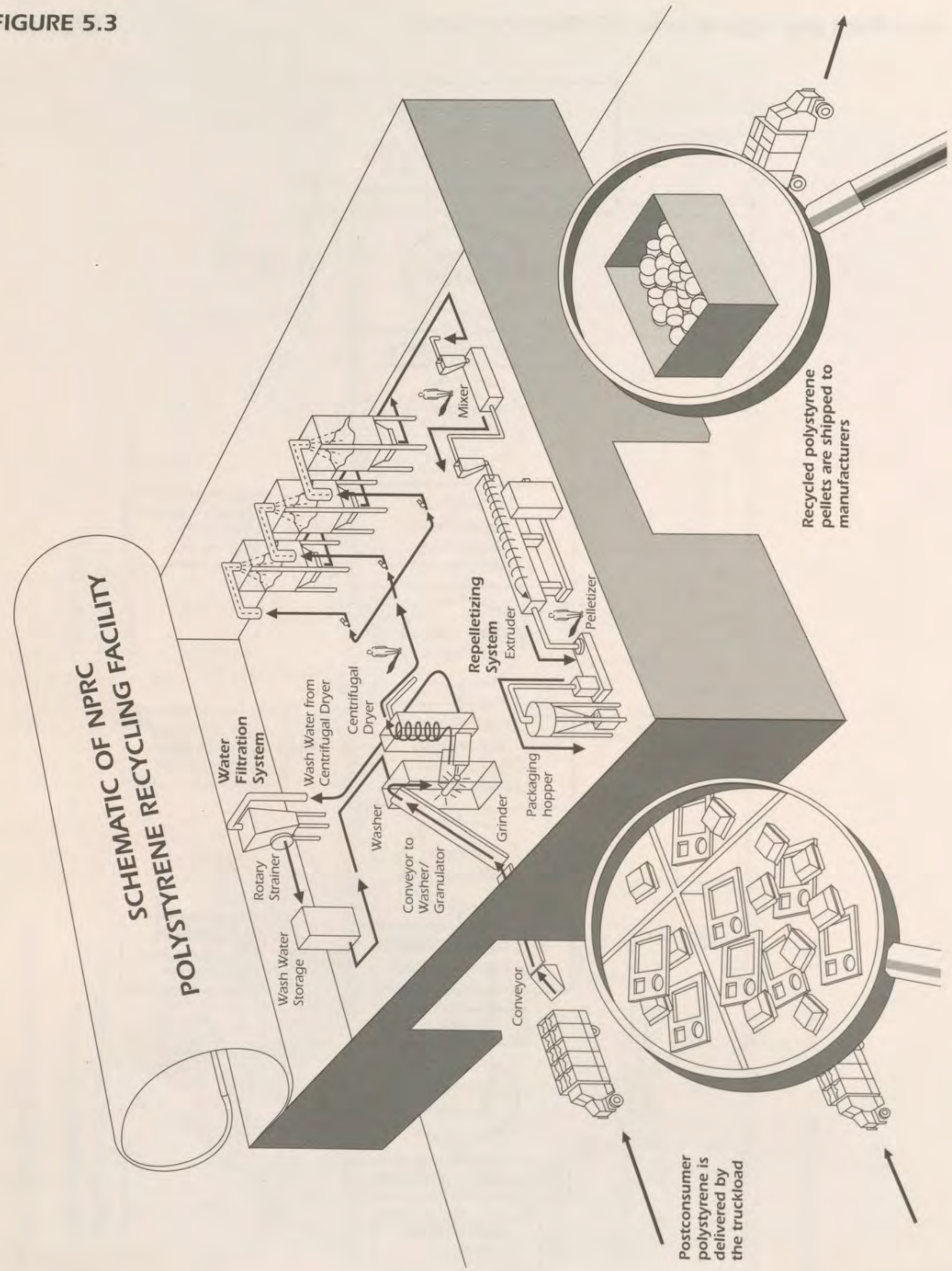


FIGURE 5.3



5. Blending and adjusting the mix to the appropriate proportion.

6. Addition of other substances (compounding), heating and extruding.

7. Molding, by compression or extrusion.

The range of temperatures for compounding and molding is regulated in such a way that the plastics requiring lower temperatures, such as polyolefines and vinyls, flow and act as binders, while those requiring higher temperatures, such as polyesters and thermosets, act as fillers. Commingled plastics processing systems, such as Recycloplast, Advanced Recycling Technology, and Sudplast involve the manufacture of plastics with minimal cleaning or sorting.

The Recycloplast technology was developed in Germany, where three industrial scrap plants using the technique are operating. The process uses feedstock that is a contaminated mixed plastic collected in the curbside program. The mix can include 50 to 70 percent thermoplastics and 30 to 50 percent contaminants and fillers. The typical melt range (for 65 percent polypropylene and polyethylene) is 180 to 200 degrees Fahrenheit. But, the range can also be adjusted to accommodate mixtures of 50 to 100 percent polyvinyl chloride and polyethylene. Coloring, fire retardants, and other fillers are added to the system in order to meet end-product specifications. Finished products manufactured from this process include pallets, grates, manhole covers, wall and flooring sheets, planter tubs, sound-absorbing walls, signpost bases, composting boxes, and cable reels.

Advanced Recycling Technologies (ART) manufactures the Extrusion Technology, or ET-1 machinery that produces "Syntal." This product can be used as a substitute for wood, metal or concrete, but cannot be molded into complex shapes. The material can be treated like wood and is resistant to salt water, chemicals, and urine. It is used, among other things, for horse ranch and cattle fencing, playground, boardwalks, road markers, and reflecting posts.

ET-1 machinery can tolerate feedstocks with up to 40 percent contamination, but operates most efficiently with formulations containing 50 to 60 percent polyethylene and propylene. One unit can produce 2.4 million pounds per year, operating at 80 percent efficiency. Syntal can be produced for 25 cents per pound, and be sold for more than 85 cents per pound. The cost per pound of raw material is only six cents per pound.

In a major improvement to existing technology, Green Tree Plastics Inc. of Victorville is developing a new approach to the reclamation of commingled plastics. The process, which will be available by mid-1992, uses chemical compatibilizers and is able to incorporate all types of postconsumer plastic wastes.

The U.S. Army Corps of Engineers is proposing a three-year project in Los Angeles for developing construction materials from commingled postconsumer and industrial waste plastics. This ambitious plan is the continuation of a test that began about five years ago using prototypes, pilings and piers supplied by Plastic Pilings Inc. of Rancho Cucamonga, California. Los Angeles officials believe the project is the largest test of plastic lumber in a marine environment.

Major objectives of the project include: 1) analyzing structural parameters, 2) evaluating the environmental and health risks associated with recycled plastic, and 3) developing detailed material specifications. The program is a joint industry-government effort.

Reclamation of Other Resins

Although PET and HDPE are the most targeted for recycling purposes, other resins such as polystyrene, polyvinyl chloride, and acrylonitrile butadiene styrene (ABS) are also being recycled. PVC bottles, for example, are being transformed into multi-layer pipes and non-food containers.

PVC can be recycled cryogenically. In the process, the bottles are shredded, then frozen with liquid nitrogen and ground while they are frozen. The resulting fine powder then is blended with virgin resin to make bottles that can be used for household chemicals, detergents, and cosmetics.

Recovered polystyrene is being used as raw material in the manufacturing of office equipment, videotape casings, flower pots, toys, insulation, combs, and garbage cans. Source separation is critical to obtain clean recycled PS resins. In the reclamation process, bales are broken, and the material is sorted, washed, dried, and extruded into pellets. (FIGURE 5.3 illustrates the steps used by the National Polystyrene Recycling Company to reclaim PS.)

Chemical Reclamation

Chemical recycling technologies are arousing intense interest because of their potential to overcome several barriers faced by mechanical plastics recycling. The conventional reclamation technologies have many economic, technologic, and marketing limitations. Collection and processing costs are high, separation methods are still underdeveloped, and the market for recycled plastics is poor.

Chemical reclamation opens the possibility to recover plastic materials thought to be difficult or impossible to recycle. The chemical approach can be useful in the recovery of medical disposables, wires, and auto shredder residues. The introduction of these technologies may improve existing markets and open new and more competitive markets for recycled plastic products.

More than a dozen major companies worldwide are working on developing 24 different chemical reclamation processes. Of these processes, five are commercial, 14 are in the demonstration stage, and five are in the experimental stage.

Some chemical recycling processes, known as tertiary recycling, take the mixed polymer stream, add solvent, and put it through an oil-refining process as an alternative feedstock to crude oil. This takes the material back into more basic hydrocarbon constituents that are transformed into gasoline, fuel oil, lubricants, as well as chemical monomers for new polymer production.

Although still in the testing phase, this avenue is especially significant for California because:

1. There is a significant oil refining industry in the state.

2. The system can use a mixed polymer feedstock without sorting.

3. The system can tolerate a reasonable degree of contamination.

4. Tertiary recycling uses existing refinery process equipment and requires only a relatively low capital cost pre-processing facility. Chemical divisions of several major oil companies—including Chevron, Mobil, Amoco, and Exxon—are researching tertiary recycling.

Using recycled plastics in food-contact containers is a reality today. Coca-Cola and Pepsi bottles are already using soft drink bottles made of chemically recycled PET. Both firms use polyethylene terephthalate that has been chemically broken down into its original components or depolymerized, and then repolymerized.

With 25 percent recycled content, the Coca-Cola bottle is rapidly penetrating national and international markets. Bottlers in California, the Southeast, the Midwest and the Mid-Atlantic regions are interested buyers. The company also plans to sell products in recycled PET bottles to Europe and Japan. Hoechst Celanese Fibers and Film Group of Charlotte, North Carolina, will supply Coca-Cola with resin for its recycled bottles. The bottle will be a blend of virgin resin with recycled resin. Further expansion will depend on availability of the recycled material and the anticipated demand from any additional markets.

Three large corporations have led in developing the chemical recycling of polyester resins: Eastman Chemicals (a division of Eastman Kodak), Freeman Chemical Corporation, and the Polyester Division of Goodyear Tire and Rubber Co. So far, depolymerization research focuses on PET, which can be broken down more easily than other packaging resins because PET contains few additives.

Recycled PET has found another application for food-contact containers. Kraft General Foods will be using salad dressing bottles made of recycled PET. The company will use the resins reclaimed by the Hoechst group.

Eastman Chemicals uses the methanolysis reaction to reprocess large amounts of reclaimed X-ray film and Kodak film scrap. In the methanolysis, a catalyst and methanol are added to clean PET scrap. The mixture is heated under pressure to force PET to depolymerize into its original components, which are then purified by recrystalization and distillation. These pure materials can be used as raw materials to produce new PET for use in a number of applications, including new bottles. A fully acceptable food-contact packaging can be obtained when mixing bottle flakes with in-plant film and X-ray film. Eastman began producing the material by the end of 1991 at its polyester recovery division in Kingsport, Tennessee. The company plans to produce about 50 million pounds of recycled resin a year.

Freeman Chemicals uses the glycolysis reaction to reprocess 25 million pounds of postconsumer PET

bottles and film scrap to produce rigid foams and laminated foam insulation. In glycolysis, a mixture of reclaimed PET resin, diethylene glycol and manganese is heated, and maleic acid added to the final product to obtain the new polyester resin. This synthetic method has been successfully tested on PET from beverage bottles.

The Polyester Division of Goodyear Tire & Rubber Company already is marketing Repete, a PET resin made from virgin and postconsumer plastic that has been de- and repolymerized. Repete resin is used by Sewell Plastics Inc. to produce 135 million Pepsi bottles a year.

Food packagers are concerned with safety and with getting approval from the Food and Drug Administration (FDA) to use recycled containers. Coca-Cola and Pepsi have FDA approval to use the PET resins reclaimed by Hoechst and Goodyear. Before Coca-Cola and Pepsi obtained permission, only one application had been approved: Dolco Packaging Corporation of Sherman Oaks, California, received FDA permission to use recycled polystyrene in egg cartons.

Although the FDA seems to be supportive of closed-loop recycling of PET bottles, many other areas of postconsumer plastic need to be examined. These areas include the source of raw material, technology used in reprocessing, the content of the resin and purity of the resin used in the final product. Two other considerations are important in chemical recycling of PET. First, the raw material should be perfectly cleaned. Using scrap plastic assures decontaminated materials and well identified resins. Second, colorless resins are preferred over colored resins.

Chemical reclamation not only means that recycled resins can be used in food packaging applications. It also opens the door to new technological and economically feasible processes for the separation and characterization of polymers from the waste stream. Tertiary recycling might provide a base for future recovery processes of new polymeric materials, such as those being used in automobiles.

A different technology has been designed by Rensselaer Polytechnic Institute of Troy, New York, in which commingled polymers are selectively dissolved in solvents, and the solid contaminants removed by filtration. Stabilizers and modifiers are added to the dissolved polymers to improve the mechanical properties of the final product. An experimental mixture of PVC, PS, LDPE, PP, HDPE and PET dissolved in tetrahydrofuran (THF) was successfully separated using fractional temperatures ranging from 77° F to 374° F.

In a similar fashion, by May, 1992, McDonald's of Munich will be testing a family of soluble polymers. Bowl, lids, coffee stirrers, and paper cups will be tested. These items, along with the food residue, will be placed in an alkaline solution. After the plastics are dissolved, the solution will be filtered to separate the food from the plastic. Once separated, the food can be composted, while the plastics can be recovered from the solution and reused in the manufacture of other products.

Argonne Laboratories is also developing solvents to separate plastics-rich residue from auto shredders into the component polymers. After sorting and removing thermosets, dissolution is conducted in acetone, tetrahydrofuran (PVC and ABS) and xylene.

The technologies of chemical reclamation have yet to mature and the environmental impacts of processes and products remain to be addressed.

Chemical reclamation economics also must be viable. Just like the mechanical technology, chemical recycling requires a large capital investment, the type that only major resin suppliers can afford. The economic feasibility of PET chemical recycling, for example, depends on several factors, such as the cost of obtaining and reprocessing the materials, the price of virgin PET resin, the supply of materials, and the scale of the reprocessing effort.

Conclusion and Recommendations

Conclusion

While curbside collection programs offer to divert the most significant variety of plastic products and facilitate documentation of plastic waste, reverse vending machines have produced the highest rate of return for plastic recyclables and allow collection of relatively pure resins. Both programs, however, are inconvenient because consumers have to store and transport materials.

Comparing curbside collection programs and determining success is difficult because of the lack of uniform and accurate data.

Materials Recovery Facilities might offer a solution to make curbside recyclables acceptable to buyers and reprocessors and to establish and maintain markets for recyclable materials. Although the number of MRFs is growing, few accept plastics on a full-scale basis, with others accepting plastics on a pilot scale.

Chemical reclamation is becoming one of the most attractive recycling technologies for plastic wastes. By using advanced chemical processes, many more plastics might be recovered, and more markets might be created for the recycled resins. Chemical reclamation is not easy, however, and needs to be proven environmentally, technically, and economically viable.

Recommendations

1. Grants should be considered for providing research and development of automated resin separation and chemical recycling technologies. This is important to reduce the costs of conventional recycling and increase the marketability of the corresponding recycled resins.

2. A computer model is needed to assist local governments in determining the best plastic collection options.

3. The shipment of plastics is expensive because of the bulky nature of many of the products and the expense of the machinery necessary to compact it. Grants and loans to local governments and non-profit organizations would help them purchase equipment to prepare recyclables for shipment, including heavy duty balers and automated sorting equipment. The awards should emphasize equipment that could be used for a region and that would not duplicate other efforts.

Chapter Six

Markets for Recycled Plastics

Introduction

Markets for recycled plastics can be divided into two types. The first market has existed for several decades and involves scrap generated by the manufacturing of resin and plastic products. Plastic manufacturers have reduced their disposal and raw material costs by selling their scrap to plastic processors who reprocess the scrap into marketable raw materials (resin pellets or flakes). The second market for recycled plastics involves postconsumer plastic wastes, which originate in residential and commercial waste streams. This market has been constrained by extensive collection, separation, and processing costs that limit the abilities of reprocessors to successfully market recycled postconsumer resins.

The small size, political sensitivity, and competitive nature of both the industrial scrap and postconsumer plastic markets create an atmosphere where reliable information is limited and analysis is difficult. Reprocessors are hesitant to reveal information about their recycled resin sales because of the intense competition between reprocessing firms. Analysis of both scrap and postconsumer plastics markets is also hampered by limited production, consumption, and trade statistics, especially statistics broken down at the state level.

The following discussion provides a general overview of plastics recycling markets. After highlighting the reasons for the comparative success of markets for industrial scrap plastics, the bulk of the chapter focuses upon the rapidly changing markets for postconsumer plastics.

Markets for Industrial Scrap Plastics

The plastics industry has supported recycling of industry-generated plastic wastes for several decades. Both resin manufacturers and plastic processors routinely reuse or sell plastic wastes such as floor cuttings, off-specification materials and overruns to plastic reprocessors. This type of recycled plastic material is commonly referred to as plastic scrap or industrial plastic waste.

Plastic scrap is typically recycled in one of two ways.

Many resin manufacturers and some plastic processors are able to recycle plastic scrap directly into their production processes without any reprocessing. This industrial practice reduces both raw material and waste disposal costs, and represents the simplest and most direct form of plastic recycling.

However, many industrial plastic wastes need to be reprocessed before they can be reused. Plastic reprocessing firms typically either pickup for free or buy plastic scrap from plastic manufacturers, then reprocess the materials into resin pellets, and sell it back to plastic manufacturers.

Recycled industrial plastic waste represents the bulk of U.S. plastics recycling activity and markets. One researcher estimated that in 1981 approximately eight percent of total resin production was recycled in plant and more than 4.7 percent by reprocessors.

A more recent study estimated that as much as 10 percent of all virgin thermoplastic resin production was recycled.

A survey of plastic recycling firms by R.W. Beck indicated that at least 1.3 billion pounds (650,000 tons) of industrial scrap plastic was recovered in 1990, a 30 percent increase from 1989.

Industrial plastic waste is successfully being recycled because of the low collection and reprocessing costs and because manufacturers avoid having to pay for disposal of the scrap. In fact, depending upon the value of the scrap to reprocessors, manufacturers sometimes generate revenue from the sale of their scrap.

Industrial plastic waste is an ideal feedstock for plastic reprocessors because it typically consists of large quantities of materials made from the same resin and without contaminants, such as dirt, glue, and food wastes. Because homogeneous and uncontaminated plastic scrap generally requires little separation

and cleaning, reprocessors incur reduced processing costs. Additionally, industrial scrap can typically be collected in large quantities in a few locations, reducing the collection and transportation costs.

The lack of contamination in industrial scrap allows reprocessors to guarantee consistent high-quality recycled resin to the manufacturer. Reprocessors have traditionally floated the prices of their recycled resin between 10-40 percent less than the price of virgin resins. Manufacturers are willing to buy the recycled resin to reduce their feedstock costs if it is relatively free of contaminants, which can reduce product quality or damage manufacturing equipment.

Considering that there are more than 300 plastic reprocessors nationwide, there appears to be sufficient incentives for both plastic reprocessors and manufacturers to develop and support a market in scrap plastics recycling without significant government intervention. Additionally, rising waste disposal costs and increasing demand for products with recycled content are likely to magnify these incentives and increase the attractiveness of the plastic scrap market to both plastic reprocessors and manufacturers.

Markets for Postconsumer Plastics

Quality and cost concerns have significantly limited the markets for postconsumer plastic resin. Certain types of plastic products, such as those products that come into contact with food, do not use postconsumer resins because of liability and/or regulatory concerns. For instance, a milk jug used to hold old motor oil or antifreeze might pose a health hazard if it was recycled into another food container. Many manufacturers who make products that do not come into contact with food also choose not to use postconsumer resins because of their concerns that recycled resin contaminants could reduce product quality, aesthetics, or damage manufacturing equipment.

The second major factor limiting postconsumer resin markets involves pricing. The markets for industrial scrap have been sustained for many years because reprocessors have generally been able to sell their product at an attractive price to manufacturers that covers their processing costs and provides some profit. However, the production of postconsumer recycled resins involves additional processing costs (sorting and washing) that can limit the ability of reprocessors to price the material attractively to manufacturers. As shown in Table 6.1, recycled resin processing costs can be up to 60 percent higher than industrial scrap costs. These additional costs result in resin prices that may be only marginally less than the price of virgin resins, especially when virgin resin prices are depressed by overproduction or price fluctuations in resin feedstocks, such as petroleum and natural gas.

Historically, the price differential between postconsumer versus virgin resin has been considered by most manufacturers to be an insufficient incentive compared to the perceived or actual drawbacks of using postconsumer materials. Additionally, manufacturers interested in using cheaper recycled resin were more likely to buy recycled industrial scrap because it typically sold for less than postconsumer materials. These trends have tended to limit the attractiveness of investment in postconsumer plastic reprocessing because of poor markets and the inability of entrepreneurial firms to gain sufficient financing from the financial community. Ultimately, the lack of demand by plastic product manufacturers limits construction of a plastics recycling infrastructure, which in turn creates few buyers for plastic wastes collected by recycling programs.

TABLE 6.1
Typical Processing Costs for Recycled Plastics

TYPES OF COSTS	INDUSTRIAL SCRAP	POSTCONSUMER
Baling	$.02 -.04 (may not be necessary)	$.02-.04
Sorting	not necessary	$.02-.03
Grinding	$.03-.04	$.03-.04
Cleaning/washing	not necessary	$.05-.15
Pelletizing	$.05-.07	$.05-.07
TOTAL	$.08-.15	$.17-.33

Source: Plastics Recycling Compendium, Chrisiansen Associates, 1990.

Exports of Postconsumer Plastic Wastes and Scrap

One result of the poor demand for recycled postconsumer materials by U.S. plastic product manufacturers has been the export of large quantities of plastic waste overseas. As shown in Table 6.2, more than 320 million pounds of plastic scrap and wastes were exported from the United States in 1989. Although industrial scrap accounts for most exports of ethylene, styrene, and vinyl chloride, the majority of U.S. plastic scrap and waste exports are classified under the enormous "miscellaneous" category. Although no further statistical breakdown of this category is available, several industry sources suggest that postconsumer wastes probably account for a significant and growing proportion of this export category.

The majority of plastic waste exports is destined for the Far East, most going to Hong Kong. Postconsumer plastic waste is typically sold to foreign markets for less than ten cents per pound, and often less than five cents per pound. However, the costs of overseas shipping can more than double the cost of the material to foreign markets. Despite this markup, importing plastic wastes is attractive to foreign reprocessors and manufacturers who typically must pay significantly higher costs to import virgin resin.

As much as 60 percent of U.S. plastic waste exports originate from West Coast ports, primarily Los Angeles, and are shipped to Pacific Rim countries. Pacific Rim processors in countries such as Hong Kong and China are able to use inexpensive labor to hand-sort plastic wastes. Hong Kong's plastic processing industry consists of more than 5,700 firms and has consistently accounted for at least 50 percent of the market for U.S. plastic waste exports. This material is typically used to manufacture internal parts of products such as toys, where slight variations in resin quality or color are acceptable.

TABLE 6.2
U.S. Plastic Waste and Scrap Exports
(in thousands of tons)

SCRAP GRADE	1989	1990	1991 Estimate (1)
Ethylene	8.1	16.4	15.5
Styrene	10.5	10.8	11.3
Vinyl chloride	8.3	11.2	13.5
Miscellaneous	118.8	152.2	162.3
TOTAL EXPORTS	145.7	190.6	202.6

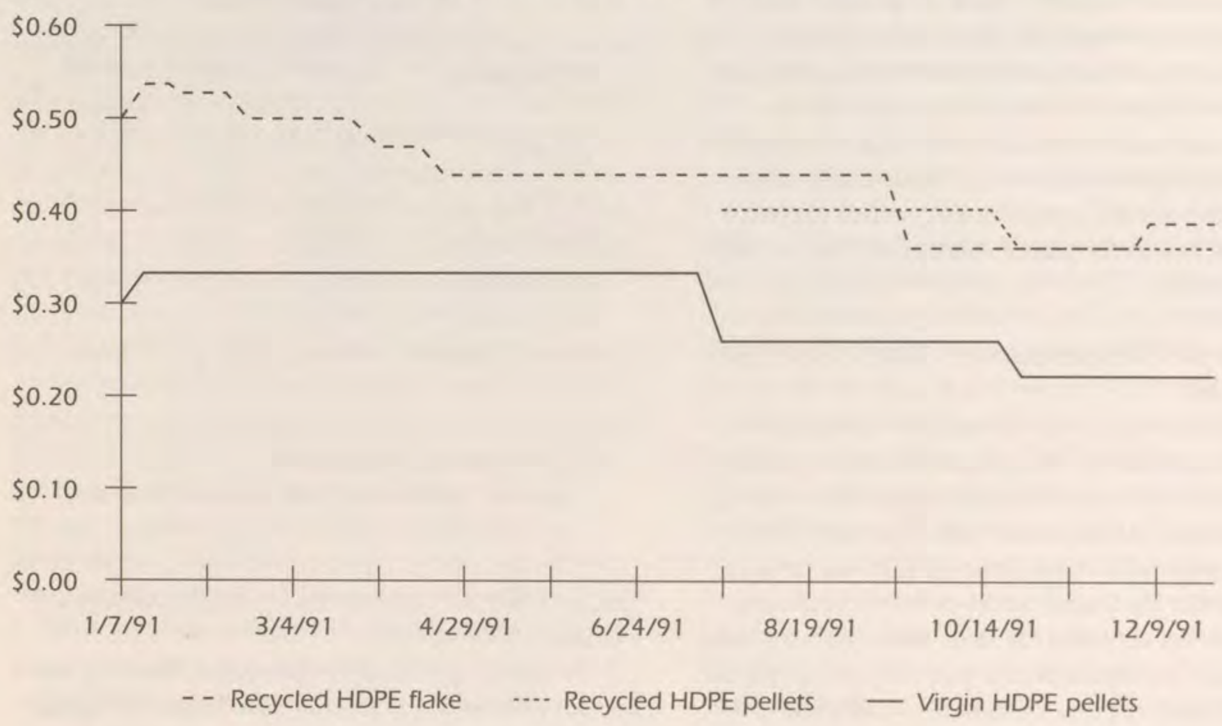
Source: U.S. Department of Commerce
(1) Estimated. Based on data for first nine months of 1991.

Recent Developments in Postconsumer Plastics Markets

During the past two to three years, domestic markets for postconsumer plastics have begun to change. Since 1988, strong interest in plastics recycling from both consumers and legislators has encouraged some manufacturers of consumer goods to develop packaging which incorporates recycled resin. Notable examples include Procter & Gamble's use of recycled resin in laundry detergent bottles and recent efforts by Coca-Cola and Pepsi to introduce plastic beverage containers with recycled content. Several states, including Wisconsin, California, and Oregon, have or are considering legislation requiring recycled content in various types of plastic products.

All of these factors created significantly larger markets for specific resin types, primarily PET and HDPE. In 1989 and 1990 demand, prices, and production of postconsumer HDPE and PET increased nationally. Demand for recycled resins, however — especially HDPE — dwindled because of a combination of factors, including the Persian Gulf War, a reduced demand for plastic during the economic recession, and overcapacity in the virgin polyethylene industry. During 1991, prices for virgin commodity plastics such as HDPE dropped significantly. As shown in Figure 6.3, the price differential between virgin and recycled HDPE shrunk significantly. As the price of virgin materials declined, manufacturers abandoned plans to buy postconsumer resins, according to many plastic reprocessors. In some cases, the

FIGURE 6.3
Average national prices for natural color HDPE



prices of virgin resin, especially to large-volume buyers, dropped to near or even below the acquisition and processing costs of some recycled resins, forcing some reprocessors out of business or to sell their resins at a loss.

Despite the troubled markets in 1991, most plastic industry analysts believe that markets for postconsumer resins will revive and ultimately prosper because of government mandates and consumer demand for products with recycled content. The markets for PET and high density polyethylene will continue to dominate the attention of reprocessors and manufacturers because these resins —in the form of bottles — are readily segregated from the waste stream. They represent roughly 80 percent of the resin used to produce plastic bottles. However, small but growing markets may develop for recycled polystyrene, low-density polyethylene plastic, and products made of mixed plastics, such as plastic lumber. Although substantial potential markets exist for polypropylene and polyvinyl chloride, these markets will continue to be limited by collection and separation problems.

Polyethylene Terephthalate (PET)

PET is the most actively recycled resin in the post-consumer plastics waste stream. Virtually all PET recycling involves beverage containers, which were introduced in 1978. Two-liter PET soft drink bottles are easily identifiable by their distinctive shape, allowing them to be readily separated from other plastic wastes by collectors.

About 30 percent (224 million pounds) of all PET beverage containers were recycled nationally in 1990, a significant increase over the 152 million pounds recycled in 1989, according to a recent study by R.W. Beck. Most PET bottles have been collected for recycling through state bottle-deposit programs. As these states maximize their PET bottle return rates, reprocessors are looking toward the increasing number of curbside collection programs to supply the growing recycled PET industry.

Like the markets for most recycled resins, demand and prices are highest for clear PET because the lack of colorants makes the material useful for a wide variety of applications. During the second half of 1991, average national prices for clear recycled PET resin pellets ranged between 43 and 50 cents per pound,

while prices for green recycled PET typically were about 20-25 percent less.

The largest market for recycled PET has been for the production of polyester fibers used in fiberfill stuffing commonly found in jackets, furniture, pillows, and sleeping bags. Five two-liter PET bottles can fill a man's ski jacket, while 36 can stuff a standard sized sleeping bag. Wellman Industries of Johnsonville, South Carolina, was one of the first markets to capitalize on the PET bottles collected under state bottle-deposit legislation. Wellman is now the nation's largest user of PET waste, consuming more than 100 million pounds of PET scrap annually. However, the company says it could consume more than 400 million pounds of PET a year if sufficient supplies were available.

Although fiberfill has traditionally been the biggest market for recycled PET, markets are growing for products such as carpet backing, PET textiles, PET film, industrial strapping, and building insulation. For instance, Wellman uses green PET bottles to make geotextile fabrics for erosion control and as linings in sanitary landfills and ponds. A 1989 study by the Center for Plastics Recycling Research at Rutgers University estimated that if recycled PET achieved a ten percent penetration of the total national PET textile market, national recycled PET demand could exceed 600 million pounds by 1993.

Since that study, a significant additional market for recycled PET has been developing for consumer bottles. Procter & Gamble introduced the first post-consumer PET bottle in 1990 for its Spic and Span pine cleaner. Since then, several other companies have introduced PET bottles made from recycled or repolymerized PET. These companies include Kraft General Foods (Kraft salad dressings), L & F Products (Lysol Pine Action cleaner), and most recently the makers of Pepsi and Coca-Cola. Like Kraft, both Coca-Cola and Pepsi have received permission from the U.S. Food and Drug Administration to use repolymerized PET in bottles that come into contact with food. In late 1991 Coca-Cola began limited bottling of their products in bottles made from 25 percent recycled PET. Although the economics of repolymerization technologies are still in question, even a modest use of recycled PET in soft drink and other PET bottles (10 percent) could result in a national market exceeding 120 million pounds annually.

In California, PET is the most recycled plastic because of its inclusion in the state's bottle-redemption program (AB 2020). Nearly all of the state's scrap PET bottles are purchased by representatives of the Plastics Recycling Corporation of California (PRCC), which represents a consortium of PET beverage container manufacturers. By purchasing all bottles collected for recycling at prices higher than the scrap value for PET, the beverage container manufacturers are able to reduce the processing fees they are assessed by the state's bottle-redemption program on each bottle they manufacture. Until recently the primary markets for this material, which exceeded 25 million pounds in 1990, have been overseas because of high overland shipping costs to East Coast markets, such as Wellman. However, the PRCC has been striving to build its sales volumes among domestic reprocessors and end users. In fact, domestic sales represented more than 50 percent of the PRCC's PET bottle sales during the third quarter of 1991.

High density Polyethylene (HDPE)

Although PET has been the focus of most post-consumer plastics recycling efforts in the United States, HDPE recycling is growing rapidly. HDPE recycling volumes will eventually far surpass PET volumes because of the vast number of consumer products made from this resin. HDPE is used to make bottles and containers for a wide range of products, such as laundry detergent, motor oil, and semi-rigid containers for certain types of food products, such as margarine and cream-cheese. Over three billion pounds of HDPE bottles and containers are produced annually, compared to about 1 billion pounds of PET containers. In 1990, only about six percent of all HDPE bottles were recycled nationally.

Prices for both postconsumer and scrap HDPE vary greatly, depending on the quality of the material and the periodic swings in price of virgin HDPE. The quality and color of HDPE wastes strongly affect the price of recycled HDPE resins.

Market prices and demand for postconsumer HDPE are highest for material made from transluscent milk and water bottles because of the lack of pigments in these containers. New pigments can be added to this material, which normally is clear or slightly green in color, to form the widest range of new products.

Recycled resins based upon mixed color HDPE bottles generally garner prices at least 20-30 percent less than uncolored materials. A few markets are beginning to appear for mixed color resins processed from certain color bottles, such as reds/oranges and

greens. The colored resins are used as an interior layer of a bottle made of similarly colored virgin resin.

Existing markets for recycled postconsumer HDPE are numerous, including base cups for PET bottles, laundry detergent bottles, motor oil bottles, flower pots, residential and commercial drainage pipe, toys, pails and drums, traffic barrier cones, milk bottle crates, and trash cans. Unlike PET, there has been little commercial-scale repolymerization of HDPE, limiting its use to non-food products. The largest markets for HDPE will involve bottles, primarily for non-food consumer products such as cleaning products, chemicals, and automotive products. The current trend for using HDPE in consumer bottles involves including internal layers of recycled resin between layers of virgin resin. Although recent bottles from bottle manufacturers such as Lever Brothers include 20-30 percent recycled resin, most manufacturers feel that higher content levels will be achieved over time. This market may reach 150 million pounds nationally by 1992.

Overall market estimates for recycled HDPE range widely because of the volatile nature of commodity resin pricing and the recession of 1991. Most industry analysts agree, however, that consumer interest and state-level mandates for recycled content packaging will increase demand for recycled HDPE over the next several years. Industry projections for demand vary widely from 600 million to 1 billion pounds by 1994.

In California, Envirothene (Chino) is the largest firm processing postconsumer HDPE. Envirothene opened its 12-million-pound-annual-capacity facility in 1991, and has been selling recycled resin to California HDPE grocery bag manufacturers, national plastic bottle manufacturers, and other plastic product manufacturers. Two other California firms that process and sell postconsumer HDPE include Talco Plastics of Whittier and Rehrig Manufacturing Company. Both process milk and water jugs. Rehrig uses its resin to manufacture plastic curbside collection bins.

Other major California markets for recycled HDPE include consumer bottle makers. A recent San Diego County study on recycled plastics identified a potential annual market for 10-20 million pounds of mixed colored HDPE at Graham Packaging Company's two southern California plants.

Polystyrene (PS)

Markets for postconsumer polystyrene are limited primarily by the collection infrastructure for waste polystyrene. But the potential market is massive. Like HDPE, polystyrene is used in a wide variety of consumer products, such as cassette casings, office equipment, videotape casings, hangers, flower pots, packaging "peanuts," toys, and insulation. Only in the last two years has postconsumer PS been used in these products. Egg cartons and hamburger "clamshells" with interior layers of recycled resin represent two new markets for postconsumer PS in food contact products.

However, the high collection and processing costs associated with postconsumer polystyrene wastes pose an expensive barrier to the development of recycled PS markets. Most PS wastes involve large volumes and low weights which require additional transportation costs or the purchase of expensive machinery to densify the waste on-site before transport to a reprocessing facility. Additionally, most PS recycling is subsidized by the plastics industry, which has concentrated its efforts upon controversial food service products that are typically contaminated with products made from other resins (e.g. polypropylene straws), food wastes, and foreign materials such as aluminum and paper. Because of these problems, most collectors receive only a nominal price for the PS waste they sell to reprocessors.

The National Polystrene Recycling Company (NPRC) was created in 1989 by eight of the largest polystyrene manufacturers to develop a national recycling infrastructure capable of recycling 250 million pounds per year, or 25 percent of the PS food service waste by 1995. This infrastructure is composed of a series of regional reprocessing facilities, two of which are in California. The NPRC's Corona and Hayward facilities both opened in 1991, and are actively harvesting polystyrene wastes primarily from institutional settings, such as schools. The NPRC's California facilities are producing the largest portion of the companies' recycled resin, which is being marketed to various buyers across the country. For example, ARCO Chemical recently introduced its Dylite brand polystyrene resins which contain 25 percent postconsumer content.

Low density Polyethylene (LDPE)

LDPE film plastics are the most common type of plastic packaging and represent an enormous source of potentially recyclable postconsumer plastic. Polyethylene packaging film production was 3.6 billion pounds in 1988. An additional 2.1 billion pounds of LDPE non-packaging film was produced for products such as trash bags, agricultural films, and disposable diapers. However, most of the LDPE waste stream is typically intermixed with food waste and other contaminants that increase reprocessing costs and can severely limit the marketability of recycled LDPE resin.

With contamination problems limiting the markets for recycled LDPE resin, most collectors and reprocessors have tended to focus upon specific sources of LDPE waste. Warehouses and some retail firms are especially valued sources because they often generate large amounts of pallet wrap and other packaging which can be segregated on-site from other waste and left relatively free of contamination. For example, Dow Chemical recently announced a joint venture with Sealed Air Corporation to annually recycle five million pounds of LDPE cushion packaging collected directly from users of the packaging.

Perhaps the most visible form of LDPE recycling involves the collection and recycling of polyethylene grocery bags in supermarkets. During the past year, approximately 30 percent of the nation's supermarkets have developed programs for their customers to return plastic grocery bags for recycling. LDPE grocery bags collected under these programs are typically reprocessed into new grocery or trash bags. However, these efforts are currently being subsidized by retail stores and bag manufacturers. Reprocessing firms and bag manufacturers say they hope to apply the experience they gain in handling and processing comparatively homogeneous wastes like grocery bags to larger and more diverse postconsumer streams of plastic films from curbside programs and materials recovery facilities (MRFs).

Despite contamination and separation barriers, industry projections forecast LDPE recycling to increase nationally from 87 million pounds in 1990 to 378 million pounds in 1993. This demand will be fueled by consumer and manufacturer interest in plastic film products with recycled content, such as trash, grocery, merchandise, and garment bags. Recycled LDPE resin can be easily mixed with virgin resin to add recycled content to plastic films as long as the films are fairly thick and do not require high amounts of color consistency. Trash bags may become an especially strong market for recycled LDPE resin because of the lower color-consistency requirements of this product.

Polyvinyl Chloride (PVC)

Recycling of postconsumer PVC faces a number of practical barriers that have discouraged both collectors and reprocessors. PVC is primarily used in construction and other applications where collectors have difficulty identifying and separating plastic recyclables. And while more than 200 million pounds of PVC resin is used annually to produce consumer bottles, collectors are reluctant to take them because the material looks so much like PET but can contaminate PET in only minute amounts. Most PVC bottles are used in a diverse number of consumer products, such as shampoo or salad oil.

As a result of these collection and separation barriers, postconsumer PVC recycling has been limited to five million pounds in 1989. The vinyl industry, however, hopes to change that; it is currently sponsoring a number of research efforts to develop economical recycling of PVC, especially for food, drug, and pharmaceutical packaging. It remains unclear whether these barriers will be overcome in the next several years.

Although collection problems are limiting PVC recycling, large potential end-product markets may exist for postconsumer PVC. One industry-sponsored study estimated potential demand for recycled PVC resin at 494 million pounds, a figure that is more than double the 207 million pounds of PVC bottles manufactured in the United States annually. These markets would involve products such as PVC pipe, siding, drains, waste and vent pipe, which could use large quantities of lower-quality resin. However, clear cut products standards will need to be developed before recycled PVC products become widely used in other types of construction products.

Polypropylene (PP)

Few if any active markets exist for recycled postconsumer polypropylene (PP). Like PVC, PP is more commonly used to manufacture products with extended lifetimes such as furniture and auto battery cases. Presently the largest source of and market for postconsumer PP comes from spent automobile battery cases, many of which are collected as a result of several state

laws regulating the disposal of auto batteries. Several automobile makers are experimenting with recycling PP scrap from old cars into new car bumpers. PP consumer bottles are primarily used for non-food products, and could represent a future market if sufficient amounts of used PP bottles are collected from the growing number of collection programs which are collecting all consumer plastics bottles.

Markets for Commingled Plastics Products

Although most plastic products require recycled resin made from a single type of resin, recently a number of new manufacturers have begun using commingled plastic waste recycling technology to make products such as plastic "lumber." Some of the largest of these firms, such as Hammer's Plastics, opened in the Midwest where there has been an increased collection of postconsumer plastics but limited access to foreign scrap markets, which created growing supplies of low-value mixed plastic wastes that many local governments have been willing to give away.

Despite the nominal cost of mixed-plastic feedstock, many of these firms have closed or are experiencing financial difficulties because of the poor markets for their products. Most commingled plastic products are priced from 50 to 200 percent higher than competing products to cover the higher labor and other overhead costs.

Manufacturers stress to their potential buyers that many products made with commingled plastics, such as fence posts and marine pilings, have extended lifespans and require minimal maintenance, qualities that ultimately make them cheaper than competing products. High initial costs, however, have proven to be a significant marketing obstacle, especially for cash-strapped government agencies that need to maximize their purchases of products such as piers, picnic tables, and benches.

In addition to pricing problems, markets for commingled plastic products have been hampered by quality problems. Buyers cite negative experiences with such products as tree poles, which rapidly warp during summer heat.

The improved reprocessing technologies for commingled plastic mentioned in Chapter 5 should reduce labor costs and quality problems. Reprocessors who are able to reduce their product costs should be able to tap into several large potential markets. Perhaps the most important of these will involve using commingled plastic forms to replace wood products, such as fence posts and highway embankment rail posts, that are pressure-treated with creasote and other toxic materials that can leach into water and soils. Other significant markets that were identified in a study by the Center for Plastic Recycling Research include landscape timbers (500 million pounds annually), pallets (370 million pounds), marine piers, and fencing for horses and livestock.

In California there are at least three firms manufacturing commingled plastic products. Plastic Pilings in Rancho Cucamonga produced mixed plastic fender piles used at a wharf facility near Long Beach. In 1991, Permaboard in Hayward began limited production of plastic lumber profiles made primarily from industrial scrap.

During early 1992, the state's largest and perhaps one of the nation's most technically advanced manufacturers of commingled plastics began operation in Los Angeles. The California Recycling Company has the capacity to annually process up to 10 million pounds of postconsumer wastes into large molded shapes (using highly automated ET-1 processing equipment) or into precision extruded profiles with solid, hollow, or foamed cores using sophisticated molding and cooling technologies developed by an Austrian processing firm.

Trends in California Markets for Recycled Plastics

A number of reprocessors of industrial scrap have operated in California for many years, primarily drawing their material from the many plastics processing firms in southern California (see Appendix 1).

Only in recent years has a small number of new or expanding reprocessing firms begun to handle postconsumer plastic wastes in California. Some of the largest of these firms include Envirothene in Chino and Talco Plastics in Whittier. Most of the state's reprocessors purchase their postconsumer plastic feedstocks from within the state, although some firms get their materials from as far as Texas. These new or expanded operations reprocess and sell postconsumer HDPE, PET, and polystyrene resin to California, national, and some foreign customers.

Although these firms represent a significant increase in the state's postconsumer reprocessing capacity, the rapid increases in drop-off and curbside collection of plastics is rapidly outstripping the capacity of these facilities. As a result, a growing proportion of the state's recyclable plastics are being shipped out-of-state. Common destinations include reprocessors on the East Coast, Washington (Partek), Texas, the Midwest, and the Far East.

California's increasing reliance upon overseas reprocessors could have several serious consequences. Most importantly, the state's plastic collection programs may become increasingly dependent upon foreign demand for plastic scrap and wastes. Foreign markets for recyclable materials such as plastics and paper have historically been volatile, with significant swings in prices and demand. California's plastic collection programs could eventually be left stranded if Far Eastern markets for postconsumer plastics became significantly depressed. For example, China's reannexation of Hong Kong in 1997 might have a negative effect upon the state's largest market for plastic scrap and wastes.

Another consequence of California's growing dependence upon overseas markets involves the state's loss of raw materials and value-added income. Similar to other recyclable materials such as paper, some of the state's collection programs are forced to sell postconsumer plastics to Far Eastern markets at prices which may not cover the collection costs of the materials. This allows foreign reprocessors to purchase their plastic feedstocks at "subsidized" prices.

Using this cost advantage and low overhead, foreign reprocessors can export recycled plastic products to the United States at highly competitive prices. If larger domestic markets and reprocessing capacity existed for recycled plastics, California might be able to retain the economic potential of the recyclable plastics. The benefits of retaining and using these resources include increased employment, corporate taxes, and sales taxes from domestic reprocessors and plastic product manufacturers who use recycled plastics.

In order for California to avoid foreign markets draining potential resources from the state's economy, consumers and legislators must continue favoring and mandating the use of recycled plastics. As mentioned in more detail in the next chapter, the Board is implementing a number of legislative initiatives that mandate recycled content in plastic bottles and trash bags, increased government procurement of products made from recycled materials, and disseminating information to industry and the public about plastic recycling and recycled plastic products. Initiatives such as these will play a key role in creating the domestic markets for recycled materials, which the state needs.

Additional research is needed to identify and develop potential markets for recycled plastics that may already exist within the state. California is home to a significant number of plastic processing firms that may represent enormous potential markets for recycled resins. As shown in Table 6.4, California is home to nearly 1,700 firms which specialize in plastic processing. Additionally, an unknown number of California firms may process plastic as part of other industrial activities. Modest increases in the use of recycled resin by these firms could absorb substantial quantities of the state's postconsumer plastics. To give an idea of the potential markets, California's plastic pipe, plastic bottle, and plumbing fixture processing sectors account for 10.2 percent, 12 percent, and 30 percent of U.S. sales.

More detailed information is needed to identify the segments of the state's plastic processing industry that will be able to increase use of postconsumer plastics. Some industries may face regulatory or other barriers that prevent them from using recycled resins. Other industries may be able to incorporate only small quantities of high quality recycled plastic in order to retain product quality. And many industries may be avoiding use of recycled materials because of the minimal difference in price between recycled and virgin resins.

As more information is gathered about these industries, research should be conducted to determine if specific incentives should be offered to plastic processors who use recycled resins. California currently offers tax credits for companies using any secondary and postconsumer materials to produce finished products.

Environmental labelling and product-award programs provide sufficient publicity incentives for some firms. However, economic incentives, such as tax credits or subsidies for recycled resin use, may be necessary to provide sufficient incentives for many plastic processors.

TABLE 6.4
Plastic Processors in California

CATEGORY	L.A. BASIN(1)	S.F. BAY AREA (2)	TOTAL CALIF. FIRMS	%OF ALL NATIONAL FIRMS IN CALIF.(3)	% OF ALL NATIONAL SALES IN CALIF. (3)
Unsupported Plastics Film and Sheet	49	6	73	12.0	6.1
Plastic Pipe	14	1	31	12.4	10.2
Plastic Bottles	24	2	35	12.6	12.0
Plastic Plumbing Fixtures	19	0	35	19.3	30.3
Plastic Products, NEC	773	186	1212	14.4	11.5
TOTAL MISC. PLASTICS PRODUCTS, NEC (4)	1094 (65%)	236 (14%)	1693 (100%)		

(1) Los Angeles, Orange, Riverside, San Bernardino Counties
(2) Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara Counties
(3) U.S. Bureau of the Census. Census of manufacture, 1987: Miscellaneous plastic products
(4) Standard Industrial Classification (SIC) 308

Source: U.S. Bureau of the Census. County business patterns, 1988: California

Conclusion and Recommendations

Conclusion

While cost incentives have readily driven the markets for industrial plastic wastes, public interest and legislation for recycled products have begun to force manufacturers to examine and increase their purchases of recycled postconsumer resins. In 1991, however, an oversupply of virgin commodity resins coupled with the recession significantly decreased both demand and prices for recycled resins, especially HDPE. Although current market conditions for recycled postconsumer resins are troubled, most industry analysts believe that public awareness and government mandates will create significant markets over the next five to ten years.

Markets for recycled PET are currently the largest and most developed. However, the vast quantities of HDPE used in consumer products will support increasingly large markets for recycled HDPE. Other common resins — such as polystyrene, LDPE, polypropylene, and PVC — continue to face collection, separation, and contamination problems that curtail the development of markets.

Although several reprocessing firms in California have begun to handle postconsumer plastics during the past few years, the bulk of the state's plastic wastes are shipped overseas to Far Eastern plastic reprocessors. One key to developing plastic recycling markets within California is in encouraging the state's sizeable plastic processing industry concentrated in the Los Angeles Basin to use recycled plastics. Increasing these markets could create a centralized plastic recycling infrastructure where collection, reprocessing, and end-product manufacture would be concentrated in southern California.

Current markets for recycled plastics divert a comparatively small portion of the plastics waste

stream from disposal. Meanwhile, industry projections forecast plastics production to continue increasing throughout the decade. Financial and logistical support by both the plastics industry and government will continue to be necessary to develop a comprehensive and stable plastics recycling infrastructure.

The Board's Market Development Committee is leading a comprehensive market strategies assessment to identify priority secondary materials, technologies, and the industries most capable of using them. The Committee will then study the best locations throughout the state to match these variables.

The Committee is focusing on HDPE, PS, and mixed plastics.

It is clear that for recycled plastics to compete for a growing share of the market:

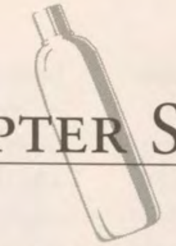
- High-quality recycled resins must be developed to compete with virgin resins.
- Performance standards must be established for recycled plastics to ensure consistent quality.
- Research grants and low-cost loans should be considered to develop less expensive collection, separation, and reclamation technologies.
- Use of recycled plastics should be encouraged through broad educational and promotional efforts.

Recommendations

1. The Board is performing a study identifying California manufacturing firms that may be able to use recycled plastics, to add to the CalMAX Materials Listing Catalog it now produces. The study will also consider if specific incentives, such as tax credits or subsidies, should be offered to plastic processors to encourage the use of recycled resins, in addition to the tax credits now available for all recycling.

2. Incentives, such as tax breaks or public awards programs, will encourage California firms to use postconsumer recycled plastics and help establish a dependable market for recycled plastics within the state.

3. Low-interest, government-backed loans would assist plastic reprocessors and manufacturers with acquisition of plastics recycling equipment. The loan program should give preference to applicants who are having difficulty securing commercial loans.



Chapter Seven

Legislative Initiatives to Increase Plastics Recycling

Introduction

From national halls of power to local town halls, government leaders have been listening to a growing number of environmentally sensitive citizens and developing numerous legislative proposals regarding recycling and waste management. Most of the activity in America is in the statehouses, where more than 400 waste management proposals were considered last year. In other countries, the federal governments have developed numerous initiatives, especially in Italy, Denmark, the Netherlands, and West Germany.

In addition, many local governments are reaching beyond their traditional role of managing waste disposal by developing laws and ordinances designed to increase recycling, encourage recycling industries, and ban the disposal of environmentally damaging products.

Legislative initiatives at all levels of government are increasingly targeting plastics because of concerns involving their slow decomposition rates in landfills and as litter.

The most common initiatives affecting plastics have included: container-deposit laws ("bottle bills"), which provide refunds for the return of certain types of plastic bottles; bans on specific types of plastic products, such as polystyrene food products or plastic packaging; and laws requiring resin identification codes on plastic containers. Nearly all initiatives at the national, state, and local levels that affect plastics can be grouped into seven general categories: deposits, bans and restrictions, mandated recycling, plastics identification, market development, packaging review laws, and taxes.

Deposits

Mandatory deposits on PET beverage containers are one of the few legislated actions that have demonstrably increased plastics recycling. Deposit initiatives typically involve the consumer paying a deposit when buying an item. The deposit is returned to the consumer when he or she returns the item. Deposit initiatives at the state government level cover a variety of items, including automobile batteries, tires, and beverage containers. Although now viewed as recycling laws, beverage container deposit laws were originally implemented to reduce the litter problems. Most plastic beverage container deposits are five or ten cents and are typically collected at the retail level. Presently PET beverage containers are the only plastic containers covered under these types of laws.

The several states that have enacted deposit legislation for aluminum, glass, and PET beverage containers are Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, Rhode Island, Vermont, and California. Additionally, some local communities have explored bottle-deposit legislation, including Berkeley. More than 2,000 pieces of container legislation were proposed between 1979 and 1983.

California's bottle redemption law, often referred to as AB 2020 (Public Resource Code §14500 et seq.), differs from container-deposit legislation enacted in other states because it attempts to cover the costs of recycling the materials within the program. In addition to consumer-paid deposits at the retail level and "refunds" at state-certified collection centers, a per-container "processing" fee is collected from beverage container manufacturers by the state's Division of Recycling. Processing fees are assessed on beverage containers with scrap values that are less than the cost of collecting and reprocessing the container. This money is then distributed to recyclers and processors to defray the costs of recycling the empty beverage containers. A processing fee of $0.00789 was imposed upon PET beverage containers beginning in 1991.

PET beverage containers are the only plastic containers regulated under current state deposit laws. PET container redemption rates for California's programs have jumped from six percent to more than 40 percent in the past two years. Still, these return rates fall considerably short of the 50-90 percent recovery

rates for PET containers attained by deposit programs in Michigan, Massachusetts, and Oregon. Unfortunately, these high return rates have occasionally created oversupply problems resulting in the landfilling or incineration of some containers. Iowa responded to this problem by implementing a law in 1990 banning the landfilling of any beverage containers.

Bans and Restrictions

Bans probably represent the most frequently proposed and most commonly rejected type of legislative initiative because of their controversial nature. During the past several years a large number of initiatives have been proposed at all levels of government to ban plastic products that are considered potentially damaging to the environment. Bans typically prohibit the manufacture, use, or disposal of an objectionable item. Opponents of bans argue that they arbitrarily interfere with the free market, while proponents typically justify bans as corrections to the free market's failure to internalize all of the economic, social, and environmental consequences associated with a particular product.

Bans are useful for specifically targeting and controlling problematic items in the waste stream that have quantifiable and verifiable negative impacts. However, bans have typically been based upon the incomplete and conflicting research, which has failed to detail all of the effects of plastic products. Bans have generally failed or not been implemented because of legal challenges. For example, Suffolk County, New York, enacted a 1988 ban on the sale of certain non-degradable food packaging, plastic grocery bags, and certain PVC and PS packaging and utensils. However, the ban has been delayed by legal challenges for several years. The cities of Minneapolis and St. Paul enacted even more stringent ordinances in 1989, banning plastic packaging that was not commercially viable to recycle. These ordinances have also been blocked by legal challenges.

Several local governments have been able to successfully enact more specific bans upon polystyrene products because they are based upon the documented damage to the Earth's protective ozone layer caused by the chlorofluorocarbon blowing agent (CFCs) used in production of PS foam. The precedents established by the successful bans in cities such as Berkeley, Palo Alto, and Santa Cruz probably encouraged the polystyrene food-packaging industry's efforts to phase out the use of CFCs. Additionally, a smaller number of local governments — including Portland and Berkeley — have banned all PS food packaging based on concerns regarding the single-use nature of these products and their slow decomposition rates in landfills. The polystyrene foam food packaging industry phased out the use of CFCs in February, 1989.

Similar to the documented threats of CFCs, numerous reports of marine pollution and wildlife endangerment secured enactment of bans upon plastic "six pack rings" across the United States. More than 20 states including California (California Health & Safety Code 24384.5) have implemented laws mandating replacing non-degradable plastic rings with degradable devices, which lessen litter and wildlife endangerment problems. Recent federal legislation will require degradable "six-pack-rings" nationwide pending a US EPA review.

Some bans have been successfully implemented by emphasizing adverse impacts upon recycling. For instance, concerns about the recyclability of the layers of plastic, paper, and aluminum found in aseptic packaging ("juice boxes") prompted a Maine ban in September, 1990. In 1986 the Coca-Cola Company briefly introduced a PET-based "plastic can" closely resembled an aluminum can. Environmentalists and the recycling industry immediately started a coordinated campaign because of concerns about the product being easily confused with aluminum cans and contaminating scrap aluminum. A successfully enacted ban in Connecticut and threats of bans in other states prompted the withdrawal of the product by the Coca-Cola Company in 1987.

European governments have generally been much more proactive in national plastics legislation than the United States. Both Denmark and The Netherlands threatened to use packaging review and control laws to regulate or ban certain types of plastic products. These threats prompted industry to redesign products and marketing strategies to encourage recycling. Switzerland recently enacted a ban on PVC beverage bottles to encourage the use of more readily recycled PET containers for which a collection infrastructure already exists.

One other ban may become increasingly prevalent: many governments are considering initiatives that ban the disposal of some or all recyclable materials in order to increase collection of recyclables. Disposal bans are becoming increasing popular in the eastern United States, where high tipping fees make waste disposal minimization a high priority. Several

states, including Massachusetts and Wisconsin, and many local governments have already implemented laws banning the disposal of PET beverage containers and other specified recyclable materials and assessing violators with warnings and fines. For example, New York City recently increased staffing to enforce recycling violations ranging from $25 to $10,000. San Diego County has been the first local government in California to adopt disposal bans.

Mandatory Recycling

Many state and local governments have enacted legislation that mandates increased collection of recyclables. State legislation typically mandates local governments to provide specific collection mechanisms for recyclables or to attain goals for collecting recyclables. Local governments generally mandate the separation of recyclables from other waste. Recycling mandates increase the quantity of recyclables by diverting them from the waste stream. The quality of recyclables can also be increased by mandates requiring the separation of different types of recyclables.

Mandatory recycling initiatives can be grouped into three general categories:

- Opportunity to recycle mandates require municipalities to offer citizens the opportunity to recycle either by developing curbside collection programs or drop-off centers.

- Source separation mandates require residences, businesses and institutions to separate their recyclables from other wastes. Many municipalities have enacted source separation mandates as part of curbside collection programs. Additionally, several states including New Jersey, New York, Pennsylvania, Rhode Island, and the District of Columbia have enacted statewide source separation laws. Many separation initiatives have concentrated upon residential wastes, but recent source separation mandates in Maine, New Jersey, Pennsylvania, Rhode Island, and Wisconsin require businesses and institutions to also separate recyclables.

- Mandatory goals require municipalities to achieve recycling or waste stream reduction goals. Municipalities are allowed to choose the methods needed to attain the goal. The California Integrated Waste Management Act of 1989 requires communities to develop and implement plans for diverting 25 percent of their waste stream from landfills by 1995 and 50 percent by 2000.

Market Development

The proliferation of mandated recycling initiatives has rapidly increased the collection of many recyclables and has contributed to oversupplies of old newspapers and glass in some regions. These supply problems have highlighted the dangers of mandating increased plastic waste collection without creating or strengthening the markets for recycled plastics. Many states have responded to this problem by implementing a variety of market development initiatives to improve the markets for recyclables collected under mandated recycling initiatives.

A large variety of market development initiatives have been adopted during the past two years at the state level. Most of these initiatives have been primarily directed toward developing markets for more commonly recycled materials, such as paper or glass. However, some initiatives directly address the recycled plastics market.

Mandated Recycled Content

One of the most direct ways of stimulating markets for recycled materials involves mandating their use in the manufacture of certain types of products. Many manufacturers, however, are concerned about being forced to use poor quality or more expensive recycled feedstocks in their manufacturing processes. Most mandated content laws have been oriented toward requiring newspaper publishers to buy recycled newsprint (California, Connecticut, Maryland, Missouri, Wisconsin).

In 1990, however, California and Wisconsin enacted the first statutes mandating recycled content in plastic products. Wisconsin's law, which goes into effect in 1995, mandates all plastic containers be made from at least ten percent recycled material unless specifically prohibited by the U.S. Food and Drug Administration.

California's first mandated content law (Public Resources Code §41970-41977) for plastics requires all trash bags to consist of at least ten percent post-consumer recycled material by 1993. In addition, the bags must be made of 30 percent recycled plastic unless they meet rigorous thickness specifications, which effectively would encourage source reduction.

In 1991 both California and Oregon enacted com-

parable statutes relating to the recycling and disposal of rigid plastic packaging containers. California's law (Public Resources Code §42300-42340), which goes into effect in 1995, includes several different options for manufacturers to comply with the mandate to use 25 percent recycled postconsumer content in the containers.

While mandating recycled content has potential for increasing the use of recycled materials in manufacturing, it can be a difficult type of mandate to impose at the state level. Programs requiring manufacturers to certify their use of recycled materials are generally expensive to administer because of the difficulties of identifying and tracking the flow of manufacturer's products within the state's borders. Additionally, individual states may have difficulties insuring that out-of-state manufacturers comply with the mandate and do not possibly gain an unfair advantage over in-state manufacturers. There are several proposals involved with the reauthorization of the federal Resource Conservation and Recovery Act (RCRA) that would mandate all U.S. manufacturers use specified levels of recycled content for various materials, including plastics.

Tax Incentives

Tax incentives involving recycling have been adopted by more than 17 states. Most of these initiatives are intended to encourage investment in recycling technologies, equipment, and facilities to assist the growth of an immature recycling infrastructure. Tax credits typically come in the form of exemptions from paying property or sales taxes, credits against state sales taxes, or deductions from corporate or individual taxable income.

In 1990, California enacted a 40 percent tax credit toward the cost of equipment used to manufacture a marketable finished product containing specified percentages of recycled material (Revenue and Taxation Code §17052.14 and §23612.5). Only a few California plastic reprocessors and manufacturers have been able to use this credit to buy grinders, washing equipment, extruders, and other equipment that is used to produce high quality plastic regrind or plastic pellets with postconsumer content.

Although a number of other states (Colorado, Florida, Maine, Oregon, Texas, Washington) have adopted or revised recycling tax credits ranging from 10 to 50 percent during the past two years, most states do not know whether the incentives have increased the amount of plastic and other materials that are recycled. For most firms, deductions on state taxes represent only a small portion of their operating costs. Most firms involved with recycled plastics manufacturing, which have tended to be small entrepreneurial firms with limited financial resources, find tax credits to be of little assistance when they are unable to secure basic startup capital.

Credit Subsidies

Credit subsidy legislation addresses the difficulties faced by many segments of the recycling sector in securing capital to buy recycling equipment and other elements of the recycling infrastructure. Credit subsidies can take a number of forms, including state-guaranteed low-interest loans, bonds, and revolving loan programs. This type of legislation is favored by many states because it often is less costly than grants, but still assists recycling enterprises that find it difficult to qualify for conventional loans because of the developing nature of the recycling industry.

Many states including Illinois, Michigan, Minnesota, New Jersey, New York, Pennsylvania, and Vermont have adopted low-interest or guaranteed loan programs designed to improve the infrastructure and markets for recycled products.

In 1989, California enacted a $5 million industrial development low-interest loan program (Public Resources Code §42145) to assist recycling enterprises within the local Recycling Market Development Zones designated by the Board (Public Resources Code §42140). While this program may prove useful to new plastic reprocessing and manufacturing firms within the zones, the amount of bond funds available to any particular applicant for the program may become increasingly limited as the Board designates additional zones each year.

Government Procurement

Procurement legislation mandates that government agencies preferentially purchase products that contain recycled materials. With government expenditures accounting for 20 percent of the gross national product, procurement legislation can provide a sizeable market for recycled products.

At least 40 states including California have enacted some form of procurement legislation. Some of these laws only provide a generic preference for recycled products and are of limited effect unless more specific criteria are provided. More than 20 states

allow price preferences for products with recycled content, typically between five and ten percent. A few local governments, such as San Jose, have adopted even more stringent measures that require buying products with recycled content regardless of price.

California's procurement legislation sets percentage goals for both state and local government agencies (Statutes of 1989, AB 4). State agencies are able to use a five percent price preference for products with recycled materials. At least 67 local governments in California are considering or have enacted procurement legislation.

In a recent study conducted by Integrated Recycling Inc. for the Board examining progress toward recycled plastic product procurement, several local governments in California indicated they already procure some types of plastic products with recycled content. Products cited included recycling containers, trash can liners and bags, printer and toner cartridges, barricade market tape, automobile parking stops, tree stakes, landscape timbers, park benches, and picnic tables. Most local governments, however, overwhelmingly buy plastic products without recycled content because of the difficulty finding information on plastic products with recycled content.

Information Collection and Dissemination

Market development legislation can also involve government collection and dissemination of information to help the recycling industry and promote the purchase of recycled products. This category of legislation covers a broad range of activities, including the compilation of statistical information relating to the recycling industry, the production of guides to recycled products, and the establishment of information clearinghouses for research, marketing, and purchasing information. California legislation adopted in 1989 mandates the Board to establish a "Plastics Recycling Information Clearinghouse" (Public Resources Code §42520). The Clearinghouse, which the Board will establish by July, 1992, will provide information about postconsumer plastic recycling to collectors of plastic wastes, reprocessors, plastic processors, and others participating in the state's plastic recycling activities.

Plastics Identification

One of the primary barriers to plastics recycling involves identifying and separating plastic wastes manufactured from different resins. Several years ago, a number of local governments began proposing legislation mandating identification of plastic containers by resin type. The Society of the Plastics Industry (SPI) responded to these diverse and sometimes conflicting proposals by developing a voluntary coding system for the plastic container manufacturing industry. The SPI introduced its standardized resin codes in 1987, and recommended that the codes be included on bottles containing 16 ounces or more and tubs containing at least eight ounces. The code consists of a number enclosed within a three-arrow triangle. Beneath the "recycling triangle" is an alphabetic abbreviation for the code.

Twenty-seven states, including California, have enacted legislation requiring coding by resin types for various types of plastic containers. Although most states use the SPI's coding system, objections have been raised about the three-arrow "recycling" triangle because it might imply that a container is being recycled when in fact it is not. California's coding legislation (Public Resources Code 18015 et seq.) is based upon the SPI coding system and requires all rigid plastic containers to include resin identification codes by January 1, 1992.

The current resin coding system may represent only a first step toward more comprehensive resin identification systems. For instance, reprocessors have raised concerns about the need to indicate different grades of the same resin, especially for incompatible blow-molding and injection grades of HDPE. Additionally, some plastic processors are including resin codes on non-container plastic products, such as plastic grocery and shopping bags.

Packaging Review Laws

Packaging accounts for a large and generally quickly discarded segment of the plastic waste stream. Packaging review and control laws create regulatory structures for controlling packaging that may present waste disposal or environmental problems. Legislative proposals have occurred at both the national and state level. However, packaging review and control laws have only been successfully implemented by some European governments.

Minnesota enacted a packaging review and control law in 1973 that charged the Minnesota Pollution Control Agency with determining the environmental impact of new or revised packages sold in the state. The law was challenged by several affected industries, but was eventually upheld by the Minnesota Supreme

Court in 1979. However, the program was never implemented because of concerns over the controversy, cost and burdensome nature of the legislation. Iowa's packaging review laws have also remained unused. Iowa passed legislation in 1987 requiring investigation of claims that the disposal of some products is incompatible with other waste management methods, such as recycling. In 1990, packaging review initiatives were defeated by voters in both Oregon and Massachusetts.

Several European counties have been much more successful with packaging review and control laws. Denmark enacted a packaging control law in 1978 which creates a number of provisions to ban or limit certain types of material, impose deposits, and require packages to contain specified amounts of recycled materials. Similar laws in the Netherlands and West Germany have been rarely used but created incentives for industry to develop plastic packaging that can be easily recycled.

In 1990, California enacted AB 3994, which makes it unlawful for consumer goods to use terms such as "recyclable," "recycled," "biodegradable," and "photodegradable" unless the goods meet specific definitions (Business and Professions Code §17508.5 and 17580 et seq.) However, the regulations do not specify an enforcement agency or other enforcement provisions beyond indicating that violations are misdemeanors punishable by imprisonment and fines not exceeding six months or $2,500.

Taxes

Many state and local governments fund waste management activities with taxes or fees. Taxes generally finance the entire spectrum of waste management activities, while fees are more commonly assessed upon individual types of wastes, such as tires or car batteries to cover the cost of their disposal. However, this terminology is often ignored. For example, states such as Utah, Texas, West Virginia, and California assess "tipping fees" upon each load of waste disposed of at landfills or incinerators. These "fees" are typically used as taxes to fund waste management and recycling programs.

Most taxation legislation targets the entire waste stream. For instance, most local governments and some state governments use tipping fees or utility taxes to fund local waste removal services and waste management programs. Several states are assessing "litter taxes" to fund various programs including litter control, recycling programs, and waste management education. Litter taxes are typically very low and have a negligible impact upon the manufacturers, wholesalers, and retailers who are impacted by these laws.

Some taxation deals with waste that is thought to pose specific waste management or environmental problems. Commonly targeted materials have included auto batteries, tires, and hazardous wastes. Plastic packaging has been the primary target of several taxation initiatives. For instance, in 1988 New Jersey considered a two-cent tax on any containers recycled at a rate less than glass or aluminum. Florida enacted legislation that imposes a one-cent tax on various types of containers if their recycling rates do not exceed 50 percent. Taxation legislation was also recently introduced in the U.S. House of Representatives calling for a 20 percent value-added tax on disposable polystyrene packaging. The proposed tax would be 20 percent in 1991, and climb to 100 percent in 1995.

The only tax currently assessed upon plastic wastes in California involves the state's bottle-deposit legislation. The "processing fee" collected by the state for each PET beverage container represents a tax to cover the costs of recycling this type of packaging. However, the concept of a "disposal cost fee" assessed upon all goods sold in the state was recently studied in a report done by the Tellus Institute for the California Integrated Waste Management Board. The results of this study will be used to develop model legislation for a comprehensive disposal-cost fee for the state.

Conclusion

California has enacted a number of laws which directly or indirectly affect plastics recycling. Most of these laws avoid highly controversial types of initiatives, such as bans and packaging review laws that have typically failed in other states. The majority of California legislation relating to plastics recycling emphasizes the development of markets for recycled materials.

Legislation in other states that bans plastics or reviews plastic packaging usually fails to be enacted or successfully implemented because they are based on faulty or insufficient scientific data about the environmental impacts or recyclability of plastic wastes. On the other hand, local bans on polystyrene products and state requirements for degradable plastic six-pack rings have been successful because of documented environmental impacts.

PET beverage containers are the only plastic containers regulated under current state deposit laws. While this legislation creates a homogeneous supply of PET to processors, PET beverage containers are estimated to account for only three percent of the nation's plastic waste stream. Inclusion of HDPE milk containers and other types of containers could lead to significant increases in the recovery of plastic wastes.

Legislation to increase recycling without corresponding market development, however, can lead to oversupply, stockpiling, and even landfilling of plastics that have been separated for recycling.

Chapter Eight

Barriers to Source Reduction and Recycling

Introduction

Although still in its infancy, plastics recycling has grown rapidly from an unpublicized industrial practice into a complex environmental and economic issue involving resin manufacturers, plastic processors, recyclers, policy makers, and the public. As recycling has grown, the barriers have become clear through many studies. Additionally, most members of both the plastics and recycling industries will readily offer numerous examples of constraints to plastics recycling (see Appendix 3 for opinions of California reprocessors).

Although emphases may differ, most of the literature and expert opinions offer similar analyses of the basic barriers to plastics recycling, which are broken down to technical, economic, informational, and regulatory barriers.

Barriers to Source Reduction

In theory, source reduction principles sound very attractive, but in practice, they are difficult to apply. The first barrier is often understanding what source reduction means because it is often confused with waste reduction. Source reduction is any action that causes a net reduction in the generation of solid waste. Source reduction is just one of several waste-reduction strategies, such as recycling and incineration.

Implementing source reduction is also difficult because it often requires economic, manufacturing and behavioral changes on a national scale. As mentioned in Chapter 4, source reduction can be accomplished by changing design and/or reducing the toxicity of a plastic product.

These changes are usually expensive because they require significant research efforts from manufacturers. Customers are also required to change longstanding buying habits and often pay more for products that are more durable, repairable, or reusable. In contrast to recycling, which can be accomplished on a local level, source reduction changes can affect the entire nation.

It is also difficult to judge the success of source reduction programs because the lack of reliable data makes it difficult to identify or measure the main contributors to the plastic waste stream, in terms of volume and toxicity.

Finally, legislators and the general public have paid more attention to hazardous waste management, through the Superfund, and to recycling than to source reduction. Contrary to the waste management hierarchy established by both the Board and the US EPA, recycling is taking precedence over source reduction.

There are some early indications that priorities are changing because of new economic directions in waste management, more concerns over the toxicity of wastes and a better understanding of waste management by the public.

Barriers to Plastics Recycling

Technical Barriers

Plastics recycling faces a number of significant technical barriers. Some of these barriers are directly related to the chemical and physical characteristics of plastics materials. Other barriers, such as contamination and separation, can involve expensive technologies, especially for postconsumer plastic wastes.

Although this report focuses on the most commonly used and recycled thermoplastic resins — such as polyethylene, polystyrene, and PET— plastic products are made from literally hundreds of different resin formulations. Many resins have distinct chemical and physical properties that make them incompatible with other resins in most recycling operations. Some resins, especially the rapidly growing number of high-performance engineering resins, are thermosetting resins that cannot be remelted and are unrecyclable with current technologies.

Plastics recycling is hampered by the lack of a complete recycling infrastructure, a structure much more complex than that required for the glass and

aluminum industries because of the greater number of different and sometimes highly incompatible materials collected. This problem is heightened by products that use several different types of resins that cannot be separated, such as multi-layer plastic bottles, making the product unrecyclable or only useful in low-value mixed grades of recycled resin. Plastics are also increasingly being used in products such as automobiles, where plastics are closely integrated with other materials such as metals and cannot be readily separated for recycling.

Physical Characteristics of Plastics

The light weight, contamination, and high volumes of many plastic wastes create storage and odor problems for waste generators, who separate and store plastic for recycling. These problems are costly for collectors, who must make more pickups than is required for other materials or invest in specially designed vehicles or densifying equipment.

Most plastic products, especially containers such as milk and PET bottles, typically have high strength-to-weight ratios compared to competing products like glass, wood, or paper. However, the strength characteristics of plastic bottles causes compressed or baled containers to "bounce back" to their original shape. This "memory" reduces the feasibility of baling plastics with ordinary vertical balers, which cost $10,000-$20,000, and requires high-density horizontal balers, which run $50,000-60,000.

Separation of Plastic Waste by Resin

Most plastics recycling technologies require at least some separation of plastic wastes and scrap by resin type, as discussed in Chapter 5. Separation is also important because resin that is homogeneous by type and color fetches significantly higher prices. The similarity of certain resin types makes complete separation difficult for both consumers and collectors. As a result, collectors or reprocessors are faced with the high labor costs of manual separation or the generally unaffordable costs of separation technologies. Separation requirements influence collectors to limit collection programs to certain types of postconsumer plastics, such as PET beverage bottles and HDPE milk containers, that are easily identified and separated from other plastic wastes and receive high prices from reprocessors.

Economic Barriers

Many of the physical barriers to plastics recycling can be overcome with existing equipment and technologies. However, most plastics recycling technologies are too expensive for many collectors and reprocessors. The combination of expensive technologies and the high cost of manual separation continue to limit the ability of collectors and reprocessors to adequately collect, separate, and reprocess plastic waste. These problems in turn create supply and quality problems that make recycled resins less attractive to plastic processors and limit the markets and applications for recycled plastics.

Collection of Plastic Waste

Collection programs for postconsumer plastic waste are often unable to fully recover costs because of the bulkiness of plastic waste. Plastics collection often involves additional storage and transportation costs not necessary for other recyclables. Additional transportation costs may be incurred by collectors who are any great distance from reprocessing firms. Many reprocessors reduce their costs by relying on uncontaminated post-industrial and post-commercial sources, leaving collectors facing the labor and equipment costs for separating their plastic wastes or receiving substantially lower prices for mixed grades of plastic waste. Some collectors also face intense and often ruinous competition from publicly subsidized collection programs.

Unreliable or Inconsistent Supplies

Stable markets are needed to stimulate the collection and reprocessing of plastic wastes. Consistent and predictable supplies are needed to develop markets for recycled resin. Seasonal fluctuations in plastic waste, such as soft drink bottles that are purchased in greater quantities during warmer summer months, can disrupt supplies and delay shipments of recycled resin to processors. Plastic processors who receive late or poor quality shipments of recycled resin are liable to shift to virgin resins to avoid quality or delivery complaints from retailers and customers.

Costs of Recycling Technology

Many collection, separation, and reprocessing technologies are proprietary or involve large capital and licensing costs. These technologies are often beyond the financial resources of the local governments and entrepreneurial firms that typically run collection and reprocessing operations. Financial institutions tend to avoid loans for recycling technologies, which often are not proven on a commercial scale. Public funding for collection equipment such as balers, granulators, and new collection vehicles often stretches local budgets. State policy makers also face tight budgets and are typically unable to justify smaller amounts of assistance to numerous local governments or the capital outlays required by entrepreneurs for individual reprocessing plants.

Insufficient Markets for Recycled Resins

Perceptions of inferior quality, as well as small and inferior supplies of recycled resin, have tended to discourage plastic processors from buying recycled resins. Good potential markets for lower-quality recycled resins — for products such as pipe, siding, and flooring —haven't been developed because they require large, reliable volumes. Health and liability concerns have limited the use of recycled resins in food packaging. Also, government specifications for products such as trash bags have tended to favor products made from virgin materials.

Informational Barriers

Plastics have traditionally been perceived as unrecyclable by the public. Until recently this perception was reinforced by a general absence of plastic recycling opportunities for most consumers. However, a growing number of plastic collection programs and industry-sponsored recycling may be altering the public's view. Representatives of both the plastics and recycling industries emphasize the importance of public education about plastics recycling to increase public support and participation.

Consumer support for plastic recycling may fade, however, when extra efforts are required to prepare plastics for recycling. Consumers who feel inconvenienced by the additional steps required by some plastic recycling programs — such as washing, removing labels and caps, and manually crushing bottles — may not participate in plastic recycling programs.

The attitudes and biases of plastic processors can also inhibit plastic recycling. Some processors resist using recycled resins because of their concerns that recycled resins lead to poor quality end-products. These processors may be able to use recycled resins in moderate quantities if the resins are of a sufficiently high quality. Other processors have consistently used recycled resins but are afraid to advertise because they fear consumers will perceive their product to be of lower quality than their competitors.

Adding to the perception of inferior quality is the lack of quality standards for plastic scrap and recycled resins. The lack of standards creates an atmosphere of uncertainty that can disrupt recycling operations and limit markets. For instance, granulated loads of plastic waste from collectors may be rejected by reprocessors because the content and quality of the load may be difficult or impossible to ascertain. Lack of standards can lead plastic processors to reject recycled resin shipments because of contamination or inferior quality, which can damage processing equipment, and lead to expensive down time and reduced quality in end-products.

Even though both plastic processors and the public may perceive products using recycled plastics as inferior materials and avoid buying them, some grades of recycled resin may have nearly identical qualities to virgin grades.

Regulatory Barriers

Some government regulations hinder plastics recycling by favoring the virgin plastics industry or other waste management options, such as landfilling or incineration. A number of other regulations can also put plastics recycling at a disadvantage. For instance, some tax laws involving depletion allowances for non-renewable resources such as oil may create inequities between the virgin and recycled plastics industries. Zoning laws can also inhibit recycling efforts by requiring recycling centers to locate far from sources of plastic waste and scrap. Regulations involving transportation tariffs, procurement, and research and development have also been cited as factors which tend to favor virgin materials at the expense of recycled materials.

In recent years, collectors and reprocessors have faced a rapidly changing regulatory atmosphere. Legislation mandating recycling and banning some products create sudden shifts in plastic waste supplies that often cause financially damaging market fluctuations. Policy makers reacting to public concerns sometimes promote regulatory measures, such as mandating the use of degradables that inhibit the economics of recycling.

Conclusion

There are a variety of physical and technical factors that contribute to the poor economic potential for postconsumer plastics recycling. Most importantly, the diverse nature of plastic resins coupled with the high volume and low weights of most plastic products complicates the collection and processing of plastic waste.

Many of these physical and technical barriers are aggravated by economic factors. The organizational and technical solutions needed for effective plastics recycling often involve enormous financial costs. Effective collection, separation, and processing of postconsumer plastic waste often prove to be too costly for many collectors and reprocessors. Because of the limited plastics recycling infrastructure, processors may face supply and quality problems with recycled resin shipments that persuade them to use virgin resins. Supply and quality problems also hamper the development of vigorous markets for recycled resins. All of these barriers tend to be aggravated by inaccurate perceptions about the recyclability of plastics and an uncertain regulatory atmosphere that discourages entrepreneurs and investors.

Appendix One

California Reprocessors and Brokers of Plastic Scrap/Waste

The following list represents firms identified by Board staff in Winter 1991 which dealt with large quantities of plastic scrap (bales or greater). Asterisked firms do not generally handle most postconsumer plastics materials, although they may handle very clean postconsumer materials such as pallet wrap. The Directory of U.S. & Canadian Scrap Plastics Processor & Buyers is a more comprehensive directory of reprocessor and brokers nationwide, and can be purchased from Resource Recycling (800/227-1424).

A & M Plastics [reprocessor]
5650 Knott Avenue
Buena Park, California 90621
(714) 523-8640
Contact: Ana Moore or Ray Boisvert

*A.D. Plastics [broker]
7100 S. Avalon
Los Angeles, California 90003
(213) 750-2575
Contact: Alvis Daras
Note: plexiglass (cast acrylic) scrap only

Al's Plastics [reprocessor]
2677 East 26th Street
Vernon, California 90058
(213) 582-4360
Contact: Alex Mendrin

*Associated Polymer Marketing [reprocessor]
700 West 1st, Suite #5
Tustin, California 92680
(714) 669-0211
Contact: Alan Zembrosky

*Bay Polymer Corporation [reprocessor]
44530 Grimmer Blvd.
Fremont, California 94538
(415) 490-1791
Contact: John LaFountain

California CRINC [broker]
5585 E. 61st Street
Commerce, California 90040
(213) 887-0844
Contact: Chip Lavigne

California Public Recycling [broker]
521 North Rice Ave.
Oxnard, California 93030
Contact: Rob Bushman

California Recycling Company [reprocessor]
3360 East Pico Blvd.
Los Angeles, California 90023
(213) 780-7999
Contact: Arie Zukerman

*Coast Polymers [reprocessor]
9368 Stewart and Gray Road
Downey, California 90241
(310) 803-8781
Contact: Jerry Malcolm

C R & R [handler]
11292 Western Avenue
Stanton, California 90680
(714) 536-7879
Contact: Michael Silva

*Engineered Resource Recovery [reprocessor]
P.O. Box 122-C
Lafayette, California 94549
(510) 283-0988
Contact: Ernie Garr

Envirothene [reprocessor]
14312 Central Avenue
Chino, California 91710
(714) 465-5144
Contact: Jason Stanton
Note: primarily handle postconsumer bottles

Escondido Sales Yard [broker]
1428 W. Mission Road
Escondido, California 92029
(619) 747-3332
Contact: Pat Hubbard

*Eureka Plastics of California [reprocessor]
4726 Everett Court
Vernon, California 90058
(213) 581-6233
Contact: Tom Bailey

Free-Flow Packaging Corporation [reprocessor]
1093 Charter Street
Redwood City, California 94063
(415) 364-1145 or 800-866-9946
Contact: Debby Hill
Note: polystyrene only

*General Plastic [reprocessor]
2623 Medford Street
Los Angeles, California 90033
(213) 227-4244
Contact: Scott Jennings

GEO Resources Recovery [reprocessor]
3050 Leonis Blvd.
Vernon, California 90058
(213) 583-5555
Contact: Sheldon Kritzer

HD Plastics [reprocessor]
4502 Brickell Privado Street
Ontario, California 91761-7827
(714) 467-3538
Contact: Ron Dempsey

*Joe's Plastics [reprocessor]
7065 Paramount Blvd.
Pico Rivera, California 90660
(213) 771-6622
Contact: Joe LaFountain, Jr.

Kingman Products, Inc. [reprocessor]
875-A Island Drive, Suite 288
Alameda, California 94501
(510) 865-1878
Contact: Bart Broome

Marketing Associates, Inc. [broker]
1818 N. Orangethorpe Park
Anaheim, California 92801
(714) 870-1840
Contact: Jack Rushing

Max Scrap Metals [broker]
21608 Nordhoff Street
Chatsworth, California 91311
(818) 709-4100
Contact: Mike Bushman

MR Plastic Recyclers [broker]
300 East Main, Suite E
Ontario, California 91762
(714) 391-2673
Contact: Bobby Martin

Oakland Plastic Sales [broker]
9733 San Leandro Street
Oakland, California 90621
(510) 562-6023
Contact: Carl Nusbaum

*Pacific Pioneer Plastic Company [reprocessor]
1642 E. 41st Street
Los Angeles, California 90011
(213) 231-4317

Pacific Plastics Engineering Corporation [broker]
15863 Channel Street
San Lorenzo, California 94580
(510) 276-6005
Contact: Michael Hong

Plastic Pilings [reprocessor]
8560 Vinyard Ave., Suite 510
Rancho Cucamonga, California 91730
(714) 989-7685
Contact: Ron Buie

Plastic Reprocessing of Southern California [reprocessor]
2470 South Santa Fe Avenue
Vista, California 92084
(619) 727-2177
Contact: Tom Long

Polymer Recovery Services [reprocessor]
3140 De La Cruz Blvd., Suite 200
Santa Clara, California 95054
(408) 748-9715
Contact: Eric Northrup

Prime Meridian [broker]
3600 South Harbor Blvd. #118
Channel Islands Harbor, California 93035
(805) 984-0871
Contact: Roger Finnell

Smurfit Recycling Company [broker]
4800 Florin-Perkins Road
Sacramento, California 95826
(916) 381-3340
Contact: Rich Garmsen

*South West Polymers [broker]
4588 Carter Court
Chino, California 91710
(714) 465-1806
Contact: Jean Kwan

Talco Plastics [reprocessor]
11650 Burke Street
Whittier, California 90606
(213) 699-0550
Contact: Todd Reagan

Talco Recycling [reprocessor]
720 S. Temescal Street
Corona, California 91719
(714) 736-7040
Contact: Phil Fusco
Note: polystyrene only

Tech Polymers [broker]
P.O. Box 4429
Berkeley, California 94704
(510) 644-1180
Contact: Augi Lamia

WeisCo Recycling [broker]
P.O. Box 21018
Castro Valley, California 94546
(510) 733-6881
Contact: Mel Weiss

Western Gold Thermoplastics [reprocessor]
815 East 61st Street
Los Angeles, California 90001
(213) 235-3387
Contact: William O'Grady

WTE Plastics Recycling [reprocessor]
30248 Santucci Court
Hayward, California 94544
(510) 429-1076
Contact: Kit Carson, Michael Grubbs
Note: polystyrene only

APPENDIX TWO

List of California Curbside Programs Collecting Plastics

The following list of curbside collection programs was compiled from information supplied by the Department of Conservation's Division of Recycling. The Division collects information on curbside collection programs in order to track the disposition of beverage containers covered under California's beverage container redemption law. As of December 12, 1990, the Division had received information from 235 programs in California, with 176 accepting PET containers, 56 accepting some HDPE containers, and 41 taking mixed plastics.

Alameda

City of Dublin	PET
City of Fremont/Newark	PET, HDPE, Mixed
City of Livermore	PET

Butte

City of Oroville	PET

Contra Costa

City of Antioch	PET, Mixed
City of Clayton	PET
City of El Cerrito	PET
City of Martinez	PET, HDPE
City of Pittsburg	PETE
City of Pleasant Hill	PET, Mixed
City of San Ramon	PET
City of Walnut Creek	PET, HDPE
Co. of Contra Costa/Pacheco	PET
Dist-Central C.C. Sanitary	PET

Fresno

City of Fresno	PET
City of Kingsburg	PET, HDPE, Mixed
City of Sanger	PET

Imperial

City of El Centro	PET

Los Angeles

City of Agoura Hills	PET
City of Arcadia	PET
City of Burbank	PET
City of Downey	PET
City of Durante	Mixed
City of Gardena	PET, HDPE
City of Glendale	PET, HDPE
City of Irwindale	PET
City of La Canada Flintridge	PET, HDPE
City of La Habra	PET
City of Los Angeles	PET
City of Manhattan Beach	PET, HDPE, Mixed
City of Monrovia	Mixed
City of Pasadena/Circo	PET, HDPE
City of Pasadena/Murcole, Inc.	Mixed
City of Rancho Palos Verdes/Waste Mgmt	PET
City of Redondo Beach	PET
City of Rolling Hills Estates	Mixed
City of San Gabriel	PET
City of San Marino/BFI	PET
City of San Marino/Community	PET
City of San Marino/Felix Disposal	PET
City of San Marino/Rodriguez	PET
City of Santa Monica	PET, Mixed
City of Sierra Madre	PET
City of Temple City	PET
City of Torrance	PET, HDPE, Mixed
City of West Hollywood	PET, Mixed
City of Westlake Village	PET
Co. of L.A./Arrow Disposal	PET
Co. of L.A./BFI District #2	PET, HDPE
Co. of L.A./Community	PET
Co. of L.A./Felix Disposal	PET
Co. of L.A./Phillips	PET
Co. of L.A./Rolling Waste, Co.	PET
Co. of L.A./Santa Clarita Valley	Mixed
Co. of L.A./Western Waste	PET, HDPE

Marin

City of Novato	PET
Co. of Marin	PET
Co. of Marin/Bolinas	PET
Co. of Marin/Stinson Beach	PET

Mendocino

City of Ukiah	PET
Co. of Mendocino	Mixed

Monterey

City of Carmel	PET
City of Marina	PET
City of Monterey	PET, Mixed
City of Pacific Grove	PET
City of Salinas	PET
District-Pebble Beach	PET

Napa

City of Calistoga	PET
City of Napa	PET
City of St. Helena	PET, HDPE
Co. of Napa/Napa Valley Disposal	PET

Nevada

City of Grass Valley	PET
City of Nevada City	PET
Co. of Nevada/Truckee/Nevada City Garbage	PET
Co. of Nevada/Truckee/Tahoe Truckee Disposal	PET

Orange

City of Anaheim	PET, HDPE, Mixed
City of Brea	PET, Mixed
City of Dana Point	PET, HDPE
City of Irvine	PET, HDPE
City of Laguna Beach	PET, HDPE
City of Orange	PET, Mixed
City of Placentia	PET, HDPE, Mixed
City of San Clemente	Mixed
City of San Juan Capistrano	PET
Co. of Orange	PET, HDPE
District-Garden Grove Sanitary	PET, HDPE

Placer

City of Colfax	PET
Co. of Placer	PET

Riverside

City of Cathedral City	Mixed
City of Indian Wells	PET, HDPE
City of Indio	Mixed
City of La Quinta	Mixed
City of Palm Desert	Mixed
City of Palm Springs	PET
City of Rancho Mirage	Mixed
County of Riverside/Jurupa	PET, HDPE
Co. of Riverside/Palm Desert Greens	PET

Sacramento

Co. of Sacramento	PET

San Bernardino

City of Colton	PET, HDPE, Mixed
City of Ontario	PET, HDPE
City of Redlands	PET, Mixed
City of San Bernardino	PET

San Diego

City of Carlsbad	PET
City of Chula Vista	Mixed
City of Coronado	PET, HDPE
City of Del Mar	PET, HDPE
City of Encinitas	PET, HDPE
City of Escondido	PET, Mixed
City of La Mesa	PET, HDPE
City of Lemon Grove	PET, HDPE
City of National City	PET, HDPE
City of Oceanside	PET, HDPE
City of San Marcos	PET, HDPE
City of Santee	PET, HDPE
City of Solana Beach	PET, HDPE
City of Vista	PET, HDPE
Co. of San Diego/Fallbrook	PET, HDPE

San Francisco

City of San Francisco	PET

San Joaquin

City of Stockton	PET

San Luis Obispo

City of Arroyo Grande	PET, HDPE
City of Grover City	PET
City of Pismo Beach	PET

San Mateo

City of Atherton	PET
City of Belmont	PET, HDPE
City of Brisbane	PET
City of Burlingame	PET, HDPE
City of Foster City	PET, HDPE
City of Half Moon Bay	PET, HDPE
City of Hillsborough	PET, HDPE
City of Menlo Park	PET, HDPE
City of Millbrae	PET
City of Pacifica	PET
City of Redwood City	PET, HDPE
City of San Bruno	PET
City of San Carlos	PET, Mixed
City of San Mateo	PET, Mixed
City of So. San Francisco	PET
City of San Mateo/Fair Oaks	PET, HDPE
District-Montara Sanitary/Montara/Moss Beach	PET

Santa Barbara

City of Guadalupe	PET
City of Lompoc	PET, Mixed
Co. of North Santa Barbara	PET
Co. of South Santa Barbara	PET
Vandenberg AFB	PET, Mixed

Santa Clara

City of Campbel	PET
City of Cupertino	PET
City of Gilroy	PET, HDPE
City of Los Altos Hills	PET
City of Los Gatos	PET
City of Monte Sereno	PET
City of Mountain View	PET
City of Palo Alto	PET
City of San Jose	PET
City of Santa Clara	PET
City of Saratoga	PET
City of Stanford	PET
City of Sunnyvale	PET
County of Santa Clara	PET

Santa Cruz

City of Santa Cruz	PET
Co. of Santa Cruz/Live Oak	PET, HDPE

Shasta

City of Redding	PET

Solano

City of Benicia	PET, Mixed
City of Vacaville/Leisure Town	PET

Sonoma

City of Cloverdale	PET
City of Cotati	PET
City of Healdsburg	Mixed
City of Petaluma	PET, Mixed
City of Rohnert Park	Mixed
City of Santa Rosa	Mixed
City of Sebastopol	PET
City of Sonoma	PET
Co. of Sonoma/Empire Waste Mgmt.	Mixed
Co. of Sonoma/West Sonoma Co. Disp.	PET

Stanislaus

City of Ceres	PET
City of Hughson	PET, HDPE
City of Modesto/Modesto Disposal	PET
City of Turlock	PET, HDPE
Co. of Stanislaus/Bertolotti Disp.	PET
Co. of Stanislaus/Gilton Solid Waste	PET, HDPE
Co. of Stanislaus/Modesto Recycling	PET
Co. of Stanislaus/R&R Disp. Inc.	PET, HDPE
Co. of Stanislaus/Turlock Scavenger	PET, HDPE

Tulare

City of Visalia	PET

Ventura

City of Fillmore	PET, HDPE
City of Simi Valley	PET, HDPE
City of Thousand Oaks/Conejo Resource Recovery	PET
City of Thousand Oaks/Conejo Valley Disposal	PET
City of Thousand Oaks/Newbury Disposal	PET, HDPE
City of Ventura	PET
County of Ventura/Ojai Valley	PET
Co. of Ventura/Environmental Recyc. Svs.	PET
Dist-Channel Islands Beach Community Svs.	PET

Yolo

City of Davis	PET, HDPE

Appendix Three

Results of California Plastics Reprocessor Survey

Introduction

For several years the California Integrated Waste Management Board has maintained a list of California firms which handle either industrial scrap or postconsumer plastic waste. The reprocessing firms identified on this list transform plastic waste into resin pellets or flakes which are typically sold to manufacturers of plastic products. Board staff developed and mailed a survey in October, 1990, to the 21 reprocessing firms included on the Board's list of plastic reprocessors. The survey was developed as a tool for Board staff to gather general statistical information and solicit comments from each reprocessor.

Survey Description

The survey consisted of two parts. The first page included four general questions about plastics recycling and the reprocessing industry. These questions were designed to solicit responses from representatives of each firm on their perceptions of barriers to their industry and the potential role of government in increasing plastics recycling. A fifth question asked the respondent to review the Board's current list of reprocessors (which was supplied with the survey) and provide contact information for any firms which may have been overlooked.

The second page involved a grid for including statistical information. Columns were assigned to 15 specific resin types. Rows were assigned to general types of information including forms of plastic waste accepted, forms and prices of reprocessed resin sold by the firm, general estimates about where a firm received its plastic scrap, and general estimates of whether the firm sold its products to in-state, out-of-state, or foreign customers.

Reprocessors were encouraged to reply to the survey by November 5th either by filling out the survey form or providing information to Board staff over the telephone. Respondents were asked to identify statistical information they chose to withhold for proprietary reasons. Firms which had not responded to the survey by November 5th received reminder calls during the week of November 5-9.

Results

As of December 20th Board staff had received nine survey forms and had conducted personal or phone interviews with two other firms. Three of the written survey responses and one personal interview identified five additional firms not on the Board's list of reprocessors. Four of these five firms were sent surveys but had not responded by the report deadline.

Statistical Summaries

Many of the statistical summaries (page 2) were partially incomplete. The tables below summarize the information provided on the eight written survey responses.

Quantity Processed (pounds/year)

Six of the nine written responses included quantity information.

	Quantity	Responses
ABS	4,200,000	5
Acetals	550,000	3
Acrylic	1,075,000	4
PET	300,000	1
HDPE (film)	5,500,000	4
HDPE (rigid)	16,100,000	4
[HDPE mixed film & rigid]	3,000,000	1
LDPE (film)	8,400,000	5
LDPE (rigid)	3,500,000	3
[LDPE mixed film & rigid]	3,000,000	1
Mixed plastics	900,000	3
Polypropylene	11,500,000	6
Polystyrene (foamed)	8,000,000	4
Polystyrene (extruded)	14,600,000	6
PVC	1,600,000	2
Nylon	875,000	3
Engineering plastics (misc.)	135,000	2
Total Quantity Processed	83,240,000 pounds/year	

Forms Accepted

Terms mentioned by respondents under the "Other" category included "virgin/reprocessed," "regrind," and "unground."

	Loose	Baled	Shred/flaked	Other
ABS	8	5	8	2
Acetals	4	3	5	2
Acrylic	7	4	7	2
PET	2	2	2	2
HDPE (film)	4	8	6	3
HDPE (rigid)	6	6	8	2
LDPE (film)	4	9	6	3
LDPE (rigid)	6	6	8	2
Mixed plastic	2	3	2	2
Polypropylene	6	7	8	2
Polystyrene (foamed)	4	6	8	3
Polystyrene (extruded)	8	8	8	3
PVC	5	4	4	2
Nylon	4	3	4	2
Engineering plastics	4	3	6	2

Forms Sold

Seven of the nine written responses included information about the forms of plastic they accept. Terms mentioned under the "Other" category included "regrind," "baled," and "densified."

	Shredded/flaked	Pelletized	Other
ABS	7	6	3
Acetals	4	2	1
Acrylic	6	2	3
PET	2	1	3
HDPE (film)	6	6	5
HDPE (rigid)	6	6	4
LDPE (film)	6	7	5
LDPE (rigid)	6	6	4
Mixed plastic	2	1	3
Polypropylene	6	7	6
Polystyrene (foamed)	4	4	4
Polystyrene (extruded)	5	6	5
PVC	3	1	3
Nylon	4	1	1
Engineering plastics (misc.)	4	2	1

Sources (estimated percentages)

Although all of the respondents provided some information, only three surveys included adequate information to be included in this summary. Virtually all of the respondants indicated that their predominant sources were post-commercial or "post-industrial." The percentages listed below indicate the percentages of plastic scrap received from different sources for three respondents.

	Post commercial	Curbside Buyback	Dropoff	Other
ABS	96%			4%
Acetals	100%			
Acrylic	100%			
HDPE (rigid & film)	97%		3%	
LDPE (rigid & film)	79%		20%	1%
Polypropylene	92%		8%	
Polystyrene (foamed)	64%	6%	24%	6%
Polystyrene (extruded)	94%		2%	4%

Sales/Price received

Respondents provided insufficient information to summarize.

Quantity Sold (to end-product users)

Respondents provided insufficient information to summarize. However, what information was provided indicated that the eleven reprocessors sold their products to a variety of different customers. Although in-state customers seemed to slightly predominate, both out-of-state and foreign customers were also common.

General Questions

All written and verbal respondents provided responses to some or all of the four general questions. The fourth question on improving the marketability of recycled products received substantially fewer responses than the other questions. This may have resulted because many if not most of the respondents are not typically involved with the marketing of finished products.

Several major themes emerged out of the eleven written and verbal responses to the survey. The three most important themes running through the surveys are summarized below. Following this summary is a more detailed listing of specific responses.

- Sorting/contamination. A large majority of the respondents emphasized the difficulties and equipment expense of sorting/removing contaminants form postconsumer plastic scrap. Poorly sorted plastic scrap, contaminants such as paper labels, and a lack of standards for scrap were identified as barriers which reduced the quality and potential value of reprocessed resin to manufacturers. Solutions offered included increased research and development activity, developing standards for plastic scrap, and increasing state-sponsored financial assistance including grants, loans, and demonstration projects to assist in the purchase of expensive processing equipment.

- Inadequate/unreliable supplies. Another commonly cited barrier involved inadequate and undependable supplies of plastic scrap. Wide variations in the quality and quantity of plastic scrap were cited as creating conditions which discouraged manufacturers from using recycled resin. A wide range of suggestions potentially related to this barrier. However, the most common suggestions involved increasing public awareness and participation in plastics recycling and encouraging the development of curbside plastics collection for both businesses and residences.

- Inadequate demand/markets. Several reprocessors believed price competition from virgin resin combined with manufacturer reluctance to use recycled resins in a variety of applications limited the demand for recycled resin. A number of solutions to these barriers were suggested including state-sponsored programs to encourage markets, mandating recycled content in plastic products, and providing incentives such as tax breaks for manufacturers to use recycled resin.

What do you feel are the most significant barriers to postconsumer plastics collection, separation, and reprocessing?

Response	Number of Responses
Sortation of postconsumer plastics expensive (labor, equipment)	6
Contamination of postconsumer plastics (e.g. paper, aluminum, degradables)	6
Inadequate funds for equipment purchases (balers, grinders, washers)	4
Lack of standards for plastic scrap	3
Public's perception that plastics are not recyclable	2
High transportation costs due to bulk of postconsumer plastics	2
Poorly designed consumer packages which are difficult/impossible to recycle	2
Inadequate or unorganized sources of plastic scrap (e.g. curbside collection)	2
High rejection rates by mills	1

What do you feel are the greatest barriers to selling reprocessed postconsumer resin to plastic manufacturers?

Recycled resin is not or is perceived not to be clean enough/low quality	8
Reprocessed resin must be sold at too low of a price due to virgin prices	5
Uncertain/undependable supplies of postconsumer scrap	4
Limited market applications/demand for postconsumer resin	3
Unable to use postconsumer resin in food-related products	1

What do you feel is the most effective step(s) state government can take to assist plastic recycling efforts in California?

Provide grants/low-interest loans for purchase of expensive equipment	5
Encourage markets for reprocessed plastics	4
Increase public awareness/involvement through education, advertising, etc.	3
Government regulators should listen to long-time reprocessors for advice	3
Mandate recycled content for plastic products	3
Encourage formation of curbside recycling for residences and businesses	3
Provide financial and administrative support for demonstration projects	2
Change restrictive procurement specifications for plastic products	2
Provide tax breaks for recyclable and/or recycled plastic products	2
Develop programs which match manufacturers with plastic reprocessors	1
Improve coordination/communication of state's agencies dealing with plastics	1
Legislate reasonable deposits on plastic containers to encourage recycling	1
Develop a research and development program for plastic technologies	1
Develop recycling centers at grocery stores	1

What do you believe can be done to improve the marketability of recycled plastic products?

Increase public awareness and involvement	3
Provide incentives for manufacturers to use recycled content	2
Mandate percentages of recycled content in plastic products	2
Research and development in new technologies and applications	2
Environmental labelling of recycled products on supermarket shelves	1
Discourage use of virgin resin through economic disincentives	1
Develop stable domestic markets	1
Unrecyclable products should be discouraged and ultimately discontinued	1

Appendix Four

Degradable Plastics

Introduction

Plastics that degrade in different environments have been proposed as one alternative to reduce the problems caused by plastics in the waste stream. For example, a great deal of interest exists for plastic items which can be biodegraded in landfills. This cannot be a realistic expectation since once a landfill is covered with soil, the amount of oxygen and water available for the degradation is very limited. First to address the issue were the environmental activists, then the legislators, and now the processors and users.

After decades of creating durable plastics, chemists have now become reverse alchemists, developing plastics which degrade in different environments. As a result, six-ring beverage carriers that crumble, plastics bags that decompose, and medical sutures that dissolve are already available. Beginning in the late 1960s and early 1970s, research efforts began to develop plastics with enhanced degradability. This research has followed two distinct courses:

1. The use of ***photodegradation***, to increase the susceptibility of plastics to degrade by the action of the ultraviolet rays. Plastics under the influence of ultraviolet (UV) radiation lose strength, become brittle, and may fall apart when stressed. Attack of the molecules may be by UV energy alone or may be by the presence of oxygen, in which case the process is called photo-oxidation.

The chemistry of oxidative degradation of packaging polymers has been widely studied over the past 30 years and is now well understood. UV is the source of initiating free radicals. It therefore triggers the series of reactions which lead to the destruction of the polymer. UV also causes the photolysis of hydroperoxides which are the source of further initiating radicals.

2. The use of ***biodegradation***, to promote the attack on the plastic by the action of bacteria. Biodegradation is generally considered to be the assimilation or consumption of substances by living organisms, but as applied to waste, it refers to microorganisms such as bacteria and fungi. In this catalytic process, the microorganisms secrete enzymes which break down the polymer molecules to products small enough to be digested by the microorganisms. The rate of decomposition depends on physical and chemical factors such as moisture, temperature, and pH.

Biodegradation is not relevant to litter decomposition because it requires moisture and burial. Photodegradation is not relevant to landfill decomposition because it requires the presence of UV radiation and oxidation.

The more readily polymers are attacked by microorganisms, the less useful they are as packaging materials whose primary function is to protect perishable goods from biological attack. The same argument can be applied to agricultural film (used to retain moisture on arable land) which is generally in direct contact with the microorganisms. The problem in all cases is that the microorganisms attack in an indiscriminate and uncontrollable manner during the useful life of the material. No simple way has yet been devised of protecting biodegradable polymers from attack until the polymer is discarded as waste.

Unfortunately, the terms photodegradation and biodegradation have been used synonymously, and people think in terms of a natural degradation, implying biodegradation plays a major role, when in reality in most instances photodegradation is the main process by which plastics degrade.

There are many unanswered questions about modified degradable plastics, particularly the contamination of food caused by the premature decomposition of the packaging material, the chemistry of degradation, and environmental concerns about the by-products of decomposition. These are some important considerations to be followed if a degradable plastic is to be used for packaging:

1. Provide acceptable performance.

2. Use conventional manufacturing technology.

3. Present acceptable economics.

4. Not adulterate the contents.

5. Its degradation products should not be toxic.

6. Resistance to microorganisms in use.

7. Be disposable with conventional technology.

8. Will not be recycled.

Items 1-4 above are of critical importance for the successful commercialization of a modified material. Commercially useful degradables already include grocery and trash bags, six-ring beverage carriers, disposable diaper liners, and some packaging. Application of degradables are useful where they provide a benefit to the environment, like plastic fish nets used in the ocean.

Photodegradation Technology

Some molecular transformations and photosensitive additives are used in the manufacture of degradable polymers. In polyethylene, for instance, carbon monoxide molecules, also referred to as a carbonyl functional group, make the material sensitive to the attack of UV radiation between the wavelengths of 280 and 400 nanometers (nm.).

One effective method of preparing photosensitive plastics is to incorporate carbonyl groups (C=O) into the polymers, using for example, carbon monoxide, methyl vinyl ketone, and methyl isopropenyl ketone. With C=O functional groups distributed at intervals along the long polymer chain, the UV energy can BREAK the chain at the carbonyl sites and make the polymer brittle. Copolymerization with carbon monoxide is the most common method of introducing carbonyl groups into plastic. The rate of degradation depends on the number of carbonyl groups added.

A similar method applicable to only low density polyethylene (PE) is to copolymerize carbon monoxide (CO) with ethylene in the manufacturing process. This method is used by several plastic resin manufacturers including Dow Chemical, Du Pont, and Union Carbide Corporation.

The rate at which the chains are broken depends on several factors, the most important being the intensity of UV radiation, the average temperature, and latitude. Objects under the shade degrade more slowly than those that are not; those in the equator will degrade faster than those in northern latitudes. Unless exposed to the sun for a long time, carbonyl modified polymers do not degrade in landfills.

Additives used singly or in combination can accelerate photodegradation. It is believed that a synergistic effect operates in such a way that the intermediate chemicals so produced might continue the decomposition reaction after burial, making the process very attractive for application in the landfill.

During the thermal process, resins may be degraded by oxygen with the production of peroxides. Antioxidants are then added to stabilize the olefins and inhibit the action of oxygen. An interesting finding is that certain antioxidants containing metal salts can protect the molecule from the formation of peroxides, and at the same time induce photocatalization, which is very desirable.

Biodegradation Technology

Efforts to produce biodegradable plastics have been directed toward the incorporation of biodegradable additives, modification of the polymer, and the enzymatic attack by bacteria.

Biodegradable additives have found some application. Such polymer additives include aliphatic polyesters, polyester diol base polyurethanes, and polylactides made from lactic acid. Polylactides and polyglycolates have been also used for degradable surgical sutures and devices.

Polymers in general, and polyolefins in particular, are not easily biodegraded. In contact with soil, some polyolefins have shown the possibility of being assimilated by the microorganisms, but the high molecular weight of the olefin inhibits significant decomposition. However, the insolubility in water of those olefins facilitates partial penetration of the enzymes from the microorganisms. Low-weight molecular photodegradable polyolefins with carbonyl groups were found biodegradable in soils. Oxygen uptake by fungi was measured, and it was estimated that the complete biodegradation took about four years. The sensitizer-containing polyethylene, previously oxidized in a weatherometer, was immersed in a culture media with bacteria. With some bacteria, the material lost a weight of 18.7 percent.

Starch Base Biodegradable Plastics

In this technology, the starch is mixed with a silane coupling agent to insure compatibility with the polymer. An unsaturated ester (corn oil) is added to act as autooxidizer. Once the article is buried, fungi assimilate the starch leaving perforations in the article. The esters react with metal salts in the soil to produce peroxides, which promote the break down of the polymeric chain. After burial, polyethylene films containing 15 percent starch decompose in six months while those containing only six percent starch, decompose in three to five years.

Degradability Testing

Different techniques are being used to determine the degree of degradation of the plastic material. The most obvious is to expose the sample to the outdoor environment according to indications given by the American Society of Testing and Materials (ASTM). The other method makes use of a device called weatherometer, which is used to control humidity, temperature, photoperiod and UV dosage. Weathered samples are then characterized using different analytical approaches including infrared spectroscopy, gel permeation chromatography, physical testing (tensile strength, elongation, etc.), thermal analyses, and scanning microscopy.

Ongoing Research Projects

1. A systematic study has been made of the degradation of polyethylene to aromatic hydrocarbons in the presence of solid catalysts. Silica-alumina was found to be an excellent catalyst for selective recovery of C3-C5 alkenes, while activated carbon catalyst impregnated with platinum, iron, and molybdenum, was found effective for the formation of n-alkane and aromatics. These results indicate that various kinds of chemicals can be obtained from polyethylene via catalytic degradation. An important consideration for this process is that in order to obtain a good yield of aromatic product, a proper combination of cracking and dehydrocyclization activities is necessary in the activated carbon. The degradation of polyethylene to aromatic hydrocarbons is an attractive reaction with regard to the recycling of plastic wastes.

2. Urea and polyols were added to starch-poly-(ethylene-co-acrylic acid) formulations to facilitate preparation, improve economics, and the quality of bio-degradable agricultural mulch. The addition of urea has been shown to improve gelatinization of the starch film. Glycerol and starch-derived polyols can also be added to increase the percentage of biodegradable component without affecting the physical properties of the film.

3. Warner-Lambert makes an all-starch plastic. Their researchers accomplished something that scientists used to believe was impossible: the production of a plastic made entirely of starch. The product is obtained by heating starch and water under pressure. The pressure enables the starch to retain the water without becoming dusty. The company has made articles by injection molding, but it has not yet developed methods for extrusion and blow molding. It will be necessary to improve some physical properties of the product. The product will probably be in the market under the trade name of Novon within three years.

4. An Austrian company has developed microbial plastic: polyhydroxy-butyrate (PHB) has been produced by bio-technologische Forschungsgesellschaft (btF), the biotechnology research unit of Austrian Industries. In the process, a mutant of the common soil bacterium Alcaligenes latus grown on a beet sugar substrate accumulates PHB at levels over 80 percent of cell mass. After fermentation and recovery, the PHB can be granulated with common extruders. btF has the capacity to produce half a ton of PHB per week, and it is supplying the product to interested companies for processing and product development studies. PHB is biodegradable and biocompatible for use in controlled release of medical implants and oral formulations.

5. Totally natural plastic: polymers produced by single-cell organisms is the exciting new research being done by Fuller and Lenz. To produce the plastic, the microorganisms are fed on glucose or molasses, and the cycle can be endless since the organisms can also use the plastic as a feedstock. Of particular note is how these microorganisms are able to produce a great variety of polymers. PHBV-Poly(3-hydroxybutirate-3hydroxyvalerate) is one of the most important from an environmentalist's point of view. The plastic can be processed into different products such as bottles, bags, and hygiene products. They can be stored and only disintegrate when they are in the water or in the soil media. They do not leave toxic residues since they degrade completely to carbon dioxide and water. The only problem the product has is its high cost compared with other starch oil-base plastics.

6. "Controlled Lifetime Polymers for Marine Application": The objective of this research is to develop degradable materials that decompose in the marine environment within a reasonable time frame. The study has focused around four areas: modified synthetic polymers, modified natural polymers, polymeric composites, and new degradable polymers. Fourteen formulations have been developed and evaluated before and after the material is contacted with seawater. Characterization analyses are done to identify changes in the molecular weight, the molecular weight distribution, and the morphology of polyethylene (PE)/polypropylene (PP)-starch (ST) composites.

Polymers have been developed that are water soluble under certain environmental conditions. Belland Co. has marketed a specialty resin which is soluble within specified pH ranges. This polymer washes away; nevertheless, the smaller pieces remain in polymeric form and are not chemically degraded. Outside the specified pH ranges, the material retains its physical properties.

Current Controversy

There are basically four interest groups involved in the controversy: legislators, environmentalists, plastic manufacturers, and degradable producers.

Some legislators in a number of states favor the production of degradable plastics by proposing bans on nondegradable plastic products ranging from egg cartons, tampon applicators and diapers to plastic grocery bags, liquor bottles and beverage rings that keep six-packs together. They also would require feasibility studies assuring that plastic products which represent a threat to fish and wildlife be degradable or recyclable.

The environmental groups declare that degradable plastics 1) will not extend the life of landfills, 2) do not solve the aesthetic problem created by litter, 3) do not reduce the threat that plastics represent to wildlife, 4) interfere with plastic recycling, 5) can pollute the environment, and 6) do not reduce, and may increase the use of plastics.

In reaction to the legislator's position, plastics manufacturers are banding together to fight for nondegradable plastics. Manufacturers advocate wider use of incineration and recycling since in most instances, degradables lack performance characteristics, which make them undesirable. Recyclers have argued that use of degradable plastics will complicate recycling by degrading the quality of recycled resins. They argue that a mix of degradable and nondegradable feedstock among recycled materials may invalidate some intended uses for reprocessed products.

Manufacturers of degradable plastics refute those charges, holding that their products decompose to carbon dioxide and water and are environmentally friendly. They consider claims made by environmentalists to be incorrect and too generalized.

The absence of the most appropriate definitions and performance standards also complicates the debate. The American Society for Testing and Materials (ASTM) organized a committee to develop standards for testing and measuring degradability. The work of the committee will be examined in an International Symposium on Standarization for Degradable Products to be conducted in January, 1991, in Washington.

Many questions remain unanswered about the degradation process, particularly questions about the rate of disintegration, effectiveness of the products, and the specific nature of by-products of the degradation. There are claims, for instance , that plastic bags used in composting systems do not degrade at the same rate as the leaves do. There are also concerns over whether degradable plastics release toxic substances (heavy metals like Pb, Cd, Ni, and Cr) into the environment. Several tests done in Lincoln, Nebraska, revealed the presence of Cd in samples taken from soil where yellow plastic bags had been buried. The best recommendation is not to use toxic materials in the manufacture of degradable plastics, which several companies are attempting to do.

Conclusion

It is important to stress that there are many unanswered questions about the rate of decomposition, effectiveness of the products, and the nature of by-products released to the environment by modified degradable plastics.

Equally important to remember is that biodegradation of plastics in the landfill cannot be a realistic expectation since once a landfill is covered with soil, the amount of oxygen and water available for the degradation is very limited.

Degradable plastics may be beneficial and cost effective for certain applications such as agricultural mulch films. However, for most applications degradability is undesirable.

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GLOSSARY

Additives: Materials that are added to plastics to give them specific properties or qualities, such as resistance to flames, oxidation, electric conductivity, as well as color flexibility.

Baler: A machine in which materials are compacted to reduce volume and provide ease in handling.

Buyback Center: A central point for collecting specific recyclables where cash payments are given—other materials may be accepted without payment.

Calendering: Plastics manufacturing process similar to spreading butter in which rollers spread melted resin over sheets of paper or cloth to form a protective finish or a strong backing; also used to produce thin plastics films and sheets by squeezing resin between sets of rollers.

Casting: Plastics manufacturing process similar to baking a cake in which melted resin is poured into a mold then chemicals are added to harden the plastic; used to shape both thermoplastic and thermosetting resins; similar to molding without the use of pressure.

Catalyst: A substance which markedly speeds up the cure of a compound when added in minor quantity as compared to the amounts of primary reactants.

Closed-loop Recycling: Turning a used recyclable product back into the same product. USFDA regulations and product liability concerns limit use of recycled plastics in food-product applications.

Commingled: A mixture of two or more plastic types that can include multi-colored resins.

Contaminant: A foreign material which adheres or combines with the primary plastic resin or produce and makes it unsuitable for recycling or reuse. Typical contaminants are paper or metal labels and closures, adhesives, other non-compatible plastics, and contents of used containers.

Curbside Collection: Collection of selected recyclable materials from residential curbsides to be brought to various processing facilities.

Dropoff Center: A central point for collecting recyclable materials. Materials are taken by individuals to the drop-off center and deposited into designated containers.

End-user: A manufacturer of finished products made from virgin or recycled materials.

Entrusion: Plastics manufacturing process similar to squeezing toothpaste in which melted plastic is squeezed through a specially shaped die in a continuous stream.

Film: An optional term for sheeting having a nominal thickness not greater than 0.010 inch.

Flake: Small particle of plastic produced by granulation, usually about three-eighths inch in size.

Foam Molding: A molding process whereby heat softened plastics containing a foaming agent is injection molded into a cavity where it hardens, producing a product having a solid contiguous skin with a foam core.

Granulation: Process by which plastics packaging is turned into flake for compaction prior to shipment.

HDPE (High-Density Polyethylene): A polyethylene plastic with longer chains and fewer side branches than LDPE. As a result, HDPE is more rigid, has greater strength, hardnes, chemical resistance and a higher melting point than LDPE.

Hauler: A transporter of recycled material from a collection site to a recycling facility.

Integrated Solid Waste Management: The practice of disposing of solid waste that uses several complementary components, such as source reduction, recycling, composting, incineration from waste-to-energy, and landfilling.

Laminating: Manufacturing process in which "sandwiches" of paper, cloth, or metal foil are treated with a plastics resin, then placed one on top of the other and squeezed together by a machine which then heats them until the resin has joined them firmly.

Landfill: A system of trash and garbage disposal in which the waste is buried between layers of earth to build up low-lying land.

LDPE (Low-Density Polyethylene): A polyethelene plastic in which the molecules are linked in random fashion, with the main chains of polymer having long and short side branches. The branches prevent the formation of a closely-knit pattern, which results in soft, flexible and tough material.

Materials Recovery: Extraction of materials from the waste stream for reuse of recycling. Examples include source separation, front-end recovery, in-plant recycling, post combustion recovery, leaf composting, etc.

Materials Recovery Facility (MRF): A facility that separates curbside collected mixed recyclables for sale to a reprocessor.

Molding: Manufacturing process in which solid resin is heated until it melts, is forced into a mold under great pressure, and then hardens to keep its shape when removed from the mold.

Monomer: A raw material, such as ethylene, used in the manufacture of a polymer.

Ozone: A thin layer in the Earth's upper atmosphere that filters out the sun's harmful ultraviolet rays.

Participation Rate: Percentage of eligible households that set out recyclables at least once per month.

Pellets: Small cylinders or ovals of solid plastic about one-eighth inch long; the primary form in which virgin thermoplastic resins are sold.

Photodegradable: The integrity of the plastic is weakened by the sun's ultraviolet rays. Spontaneous breaking occurs, causing the product to be reduced to small pieces.

PC (Polycarbonate): PC is characterized by clarity (with optical applications), impact strength and heat resistance. PC is more often used in durable goods production than disposable goods. Typical applications are found in glazing, appliances, and electrical uses. An easily recognized PC product is five-gallon water cooler bottles.

PE (Polyethylenes): A family of resins composed of polymers of ethylene. It is normally a translucent, tough, waxy solid which is unaffected by water and by a large range of chemicals. Some different forms are L/LDPE and HDPE. Major applications include packaging, housewares, toys, and communications equipment.

PET (Polyethylene Terephthalate): A saturated thermoplastic formed by condensing ethylene glycol and terephthalic acid. Is is extremely wear and chemical resistant and dimensionally stable. It also has a low gas permeability in comparison to HDPE, LDPE, PP, and PVC which is why it is used so extensively for carbonated beverage bottles.

Plastics: Any of numerous organic synthetic or processed materials that are mostly thermoplastic or thermosetting polymers of high molecular weight and that can be molded, cast, extruded, drawn, or laminated into objects, films, or filaments.

Polymer: A chain of repeating molecular units linked through polymerization.

Polymerization: Process by which monomers are transformed into specific polymers by using different additives, catalysts, and variations in temperature, pressure, and reaction time.

Polypropylene: A tough, lightweight rigid plastic made by the polymerization of high-purity propylene gas in the presence of an organo-metallic catalyst at relatively low pressures and temperatures.

Polystyrene: A water-white thermoplastic produced by the polymerization of styrene (vinyl benzene). The electrical insulating properties of polystyrene are outstanding and the material is relatively unaffected by moisture.

Polyvinyl Chloride (PVC): A thermoplastic material composed of polymers of vinyl chloride; a colorless solid with outstanding resistance to water, alcohols, and concentrated acids and alkalies. Compounded with plasticizers, it yields a flexible material superior to rubber in aging properties. It is widely used for cable and wire coverings, in chemical plants, and in the manufacture of protective garments.

Postconsumer Material: Any product that has been used by the consumer and discarded.

Reclamation: Enhancing the quality of a recovered material to meet the market requirements.

Recycling: The process of collecting, sorting, cleansing, treating, and reconstituting materials that would otherwise become solid waste, and returning them to the economic mainstream in the form of raw material for new, reused, or reconstituted products that meet the quality standards necessary to be used in the marketplace.

Regrind(verb): To grind or shred scrap plastic for reuse in manufacture of a product. (noun) The cleaned and shredded scrap material usually mixed with virgin resin for remelting and reuse. Applies to thermoplastics only.

Reinforced Plastics: Strong, lightweight combination of plastics with glass fibers, cloth, or paper.

Reprocessing: Reclamation of used raw materials for use in the manufacturing of new products.

Resin: Generic term for synthetic plastics following manufacture and pelletization.

Resource Recovery: The extraction and utilization of materials and energy from the waste stream. Recovered materials are used in the manufacturing of new products, or converted into some form of fuel or energy source.

Scrap, In-house: Any material resulting from plastic product manufacturing that is not part of, or reusable as, the primary product. In thermosetting molding, this includes flash, culls, runners, and is not reusable as a molding compound. Injection molding and extrusion scrap (runners, rejected parts, sprues, etc.) can usually be reground and remolded.

Scrap, Postconsumer: Plastic waste materials or used products which have been used as an end-product or manufactured into a secondary product and discarded. Differs from in-house scrap in that the plastic material has usually been exposed to other materials which contaminate the original plastic resin and must be removed for recycling.

Set-out Rate: The percent of eligible households that set out their recycling container in a given week.

Solid Waste: Garbage, refuge, sludge, and other discarded solid materials, including those from industrial, commercial, and agricultural operations, and from community activities.

Solid Waste Management: The systematic administration of activities that provide for the collection, source separation, storage, transportation, transfer, processing, treatment, and disposal of solid waste.

Source Reduction: Any action that causes a net reduction in the generation of solid waste. It includes the reduction of both volume and toxicity.

Source Separation: The segregation of various materials from the waste stream usually at the point of waste generation.

Thermoplastics: Resin that are hardened merely by being allowed to cool; products made from these resins melt when heated.

Thermoset: Resin manufactured by adding heat and applying pressure while the resin is in a mold causing chemical changes that make the resin hard; products cannot be remelted.

Tipping Fee: A fee for the unloading or dumping of solid waste at a recycling facility, landfill, transfer station, or waste-to-energy facility, usually stated in dollars per ton.

Transfer Station: A facility where recyclables or waste materials are taken from smaller collection vehicles and transhipped in larger units for movements to disposal sites. Some sorting and separation of recyclables may take place.

Volume Reduction: The processing of waste materials so as to decrease the amount of space the materials occupy. Reduction is accomplished by mechanical, thermal, or biological processes.

Waste Stream: The waste material output of an area, location, or facility.